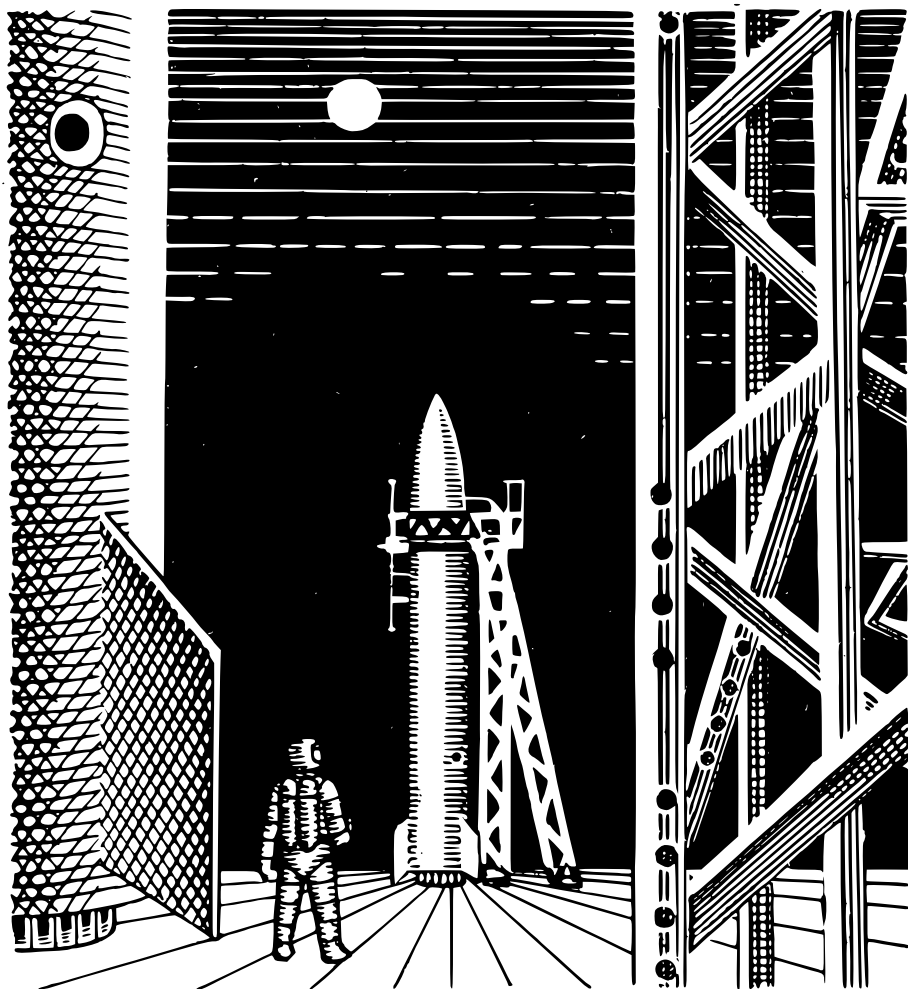
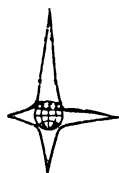


M. Rebrov, G. Khozin

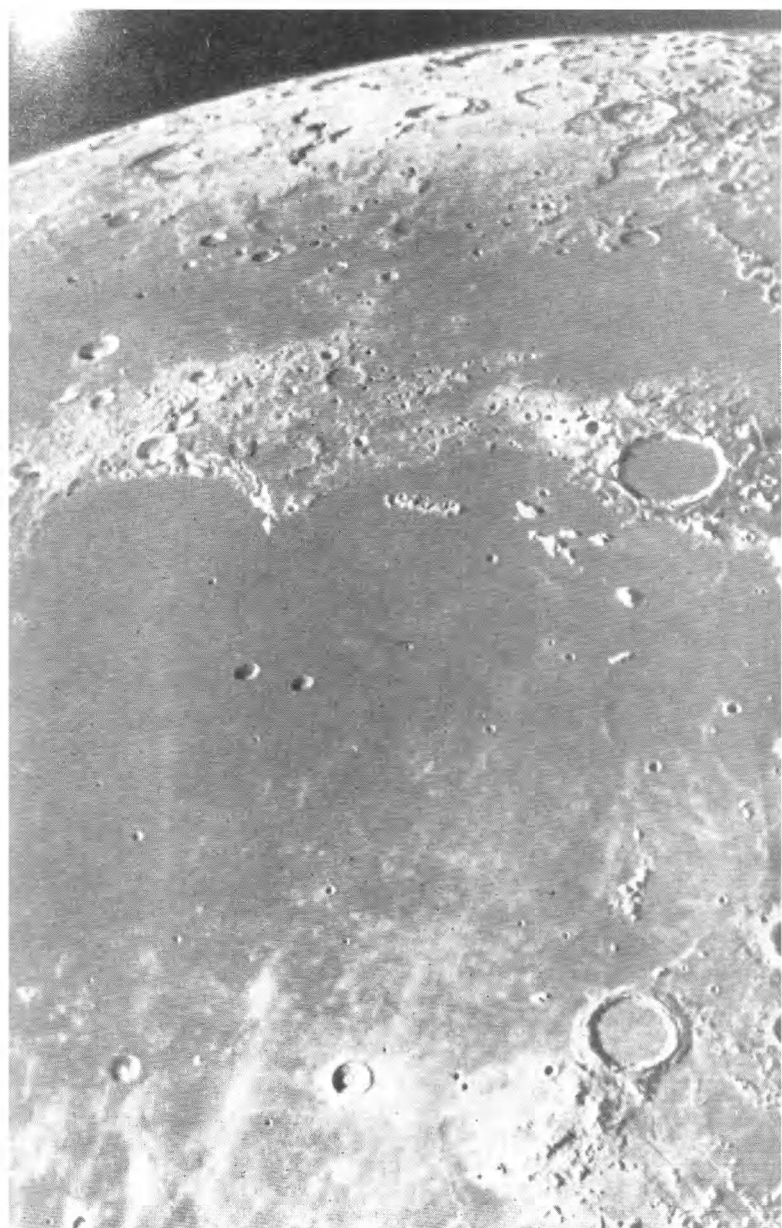


THE MOON AND MAN



PEACE
PUBLISHERS

На английском языке



M. REBROV

G. KHOZIN

THE MOON
AND
MAN

PEACE PUBLISHERS

MOSCOW



М. РЕБРОВ,

Г. ХОЗИН

НАС
ЖДЕТ
ЛУНА

ИЗДАТЕЛЬСТВО «СОВЕТСКАЯ РОССИЯ»

МОСКВА

UDC 629. 192. 32(0.23)=20

**Translated from the Russian
by Vladimir Talmy**

CONTENTS

By Way of an Introduction . . .	9
1. The Promise of Outer Space	11
2. Moon Fables	18
3. Birth of a Dream	22
4. What We Know about the Moon	27
5. Hypotheses and Theories	34
6. Hazards of Outer Space . . .	44
7. Automatic Explorers	48
8. Leaving the Earth	59
9. Rocket Engines . .	69
10. The Path to the Moon . . .	77
11. Moon Projects .	84
12. Robots on the Moon	102
13. The First Men on the Moon	106
14. The Call of the Cosmos . . .	115

I Dream
of Flying Round
the Moon

We were speaking of the not-too-distant time when man will set off on flights to the moon and planets of the solar system. "Do you cosmonauts dream of future flights and what planet would you fancy?" one correspondent asked me.

Cosmonauts do dream, of course. We have a lot of work, but in our spare time we like to talk about what we may see someday on the moon or Mars or Venus. As for myself, I dream of flying round the moon. Many people would like to visit the moon. But we must first ask why men should fly to the moon and only then discuss the flight itself. Today we can dream in more specific terms than we could

before the time of space flights. We can speak in matter-of-fact terms, although it might be hard to say just what a lunar spaceship will look like and what the first lunar flight programme will include. Flight to the moon will evidently be preceded by a flight around it. It may be necessary to solve such problems as placing extra-heavy satellites in orbit round the earth, setting up manned interplanetary stations, etc., before a moon launching is undertaken.

In any case, I suppose that today's cosmonauts have a good chance of getting a close view of the moon. And then we'll probably have to hand over to those who fly to Mars and Venus.

Gherman Titov

*
* THE DOORS
* INTO SPACE
* ARE OPEN

*

*

*

*



* *(By way of*
* *an introduction)*

*

For ages people dreamed of having wings. Like the legendary Icarus, men wanted to fly to the sun, and visit and explore the distant worlds twinkling in the skies above. Today men look up into the star-spangled sky with new and redoubled interest. The idea of flying into outer space and circumnavigating the globe is no longer a dream. Ever since the day in April 1961, when Yuri Gagarin made his epoch-making flight in space, obstacles which had once seemed insurmountable have come to be defined in specific terms of engineering design. Mankind is prepared for the great moment when explorers of the universe will embark on their ambitious missions.

The great advances in astronautics have excited people's interest in interplanetary flight. When Sputnik 1, the world's first artificial earth

satellite, was launched it heralded the beginning of a new era in the history of man's conquest of nature. By their exploit Soviet scientists and engineers opened the doors into outer space. Each new space flight is another step up the ladder into the great unknown.

Men are contemplating flights to other planets. Naturally enough, this gives rise to many questions. Is interplanetary travel possible at all? When will the first interplanetary flight take place? What can be gained from space conquest? And where lies the boundary between fantasy and reality?

Our closest neighbour in space, the moon, lies at a mean distance of 384,000 kilometres (240,000 miles) from the earth. A car travelling at 100 kilometres per hour (62 mph) would reach it in half a year; a jet airliner would take only half a month; a Vostok spaceship travelling at 28,000 km/hr (17,400 mph) would take just over half a day. The moon is, obviously, best suited to be man's first target in space.

A journey to the moon is today a realistic proposition, and many people are actually working to bring it about. Some of the problems confronting them, and the ways and means of reaching the moon and other planets of the solar system are discussed in the following chapters.

✱

✱ 1. THE PROMISE
✱ OF OUTER
✱ SPACE

✱

✱

✱

✱

✱

✱

Is outer space as important to man as we are made to believe? Are people so crowded on earth that they have to go on searching for other worlds? What useful purpose is served by designing vehicles for interplanetary flight? Are not some scientists a bit too enthusiastic? What can be gained from flights to other planets? Will man's efforts in reaching this goal ever pay off intangible results?

These and many other questions are asked daily by both starry-eyed enthusiasts all out for space research and bleary-eyed sceptics who regard it as premature, to say the least. Obviously, there is no brief answer, although, for the benefit of the sceptics, at least one could be offered right away; the unique resources of the moon would alone suffice to recompense all the expenses

incurred in getting there. The exploration of outer space will help people to solve many of nature's secrets and many practical problems at home. Here are several examples.

Artificial earth satellites have already altered many preconceived notions about the earth. They have been used to measure its radius to an accuracy of 10 metres (30 feet) and to pinpoint the position of geographic features. They provide the backbone for a worldwide meteorological service. A station on the earth can record only passing weather changes; orbiting laboratories can present a comprehensive picture of weather movements and changes. When man learns to forecast the weather correctly he will come closer to learning to control it. The day will surely come when he will be able to direct rain to arid regions, disperse mists and contain typhoons. Weather forecasting and control will ultimately more than pay back the cost of all the meteorological satellites ever to be launched in terms of the many human activities dependent on the weather. With detailed and reliable weather forecasts farmers will be able to decide just when to plant and harvest crops to ensure the highest yield; air travel will become as reliable as railways; and fishermen at sea will no longer be caught unawares by sudden storms. Reliable prediction of hurricanes, storms and typhoons will enable people to prepare for them in advance, thus reducing possible damage to a minimum.

In another field, artificial satellites have told scientists that the earth is surrounded by huge belts of radiation reaching out some 80,000 kilometres (50,000 miles). They undergo important

variations associated with the development of sunspot cycle, and these phenomena are further related with changes in the rhythm of the earth's rotation on its axis.

Space laboratories have also told scientists that the earth dissipates some 100 tons of hydrogen daily due to evaporation from the surface of the oceans and, on the other hand, thousands of tons of iron fall to earth in meteorites and meteoritic dust.

New vistas are opening up in radio, telegraph and telephone communications. The transatlantic cables between Europe and America are operating at peak capacity, yet requirements are steadily increasing. Soon satellites will be used to handle intercontinental communications. Television stations can broadcast programmes no more than 150-200 kilometres (90-120 miles) without intermediate relay stations. Communication satellites will be able to relay images to any point of the globe, and audiences in Moscow, London, New York, Melbourne, Tokyo or Buenos Aires will be able to view the same programmes simultaneously. Experimental transmissions of telegraph, audio and visual signals have been carried out by bouncing them off the moon and one day the moon itself may be used as a relay station. Television and high fidelity sound broadcasting is carried out at ultrahigh frequencies in the metre waveband. But these waves cannot skirt the earth's curvature. Bouncing them off the moon may help to solve the problem of intercontinental television. We may even hear one day of postal satellites for express letter delivery.

Navigation satellites will enable oceangoing ships and intercontinental aircraft to determine their positions to an accuracy of 100 metres (300 feet). The importance of this can hardly be overestimated.

Colonization of the moon will be useful for establishing permanent astrophysical observatories unhampered by an atmosphere, antennae for cosmic radio communications, and refuelling stations for distant space flights. "Cells" of human habitation will spring up around storage depots, repair shops, research installations and power plants. It is on the moon that Konstantin Tsiolkovsky's "ether cities" will finally become a reality—with the necessary corrections introduced by the progress of science since his time.

Man's emergence outside the atmosphere will give new impetus to radio-astronomical research, both passive, which is the study of radio emission of stars, planets and other celestial objects, and active, which is the sounding of extraterrestrial bodies by means of radar. The achievements of space electronics will find numerous applications on earth, notably in the automation of industry and farming, in enhancing the speed and capacity of communication systems, in biology, medicine and many other spheres of human endeavour.

The moon could be used as a power supply base for the earth; with its surface could be covered with semiconductor photocells capable of converting sunlight into electric power which could be delivered to earth by bundles of carrier beams. Thermonuclear power plants on the moon would eliminate once and for all the pro-

blem of radioactive contamination and disposal on earth.

Advances in space flight systems will also find terrestrial applications. Thus, temperature control in the cabin of a spaceship is essential for normal working conditions of the crew and operation of spaceborne equipment. Progress in this field will result in the development of cheaper and better air conditioning systems for use on earth. The special fabrics used to make parachutes to help spacecraft land safely can be used in construction. Already today, a derivative of hydrazine developed during work on rocket fuels is being used successfully in the treatment of tuberculosis and certain mental disorders. Fuel developed for space flight will be used to advantage for earth-bound transport. Flight control and safety systems will be employed in aircraft, ships and automobiles. Gadgets and devices which contribute to astronauts' safety and comfort in flight will be widely used for similar purposes on earth.

These practical applications of astronautics are but one aspect of the new science, and not even the most important one. For the primary value of astronautics lies in the great vistas which it opens up for new breakthroughs in science. Up to now man has lived on earth as if in an incubator. When he studies matter in outer space he will surely discover new properties about which he can only speculate today. New forms of matter produced in laboratory conditions serve as the point of departure for new theories and technological advances. In outer space matter exists largely in "plasmic" state, in which atomic nuclei are stripped of their electrons and do

not readily recombine into atoms as on earth. As a result of the chaotic motions of negatively charged electrons and positively charged nuclei plasmas have an electrical conductivity thousands of times better than that of copper. Plasmic matter, the study of which was recently pioneered by nuclear physics, obeys the laws of a new kind of physics called magnetohydrodynamics.

Outer space holds promise of many remarkable discoveries, and human accomplishments in the exploration of the universe will profoundly affect life on our little planet and, someday, in distant parts of the universe as well. Other worlds probably harbour forms of life which are naturally organized in accordance with the conditions prevailing there. Gravity on the moon is much less than on earth, on asteroids it is negligible, and on Jupiter it is more than 2.5 times greater than terrestrial gravity. The temperature on the side of Mercury facing the sun is hundreds of degrees above zero, while on distant Pluto it is 260 degrees Celsius below. The moon has no atmosphere and its surface is directly subject to all the effects of outer space. Venus has an atmosphere which may prove similar to the earth's. In fact, V. Prokofyev at the Crimean Astrophysical Observatory has found oxygen in the atmosphere of Venus, while Moscow astronomer V. Morozov has discovered six new lines in its spectrum, three of which are attributed to common carbon dioxide and to carbon dioxide with a different carbon isotope (the three other lines have not yet been identified). Jupiter's atmosphere apparently consists largely of hydrogen, ammonia and methane, and Saturn is

claimed by some to be a huge sphere of solid hydrogen.

But the moon is our closest neighbour in space and it is hardly surprising that our immediate plans of interplanetary flight are associated with it. A flight to the moon may offer new data for reconstructing the history of the solar system and the earth. Obviously, it is still too early to anticipate all that man can gain from these ambitious undertakings, but we may be quite sure that knowledge of the moon, solar activity, other planets and stars will contribute to human progress, science, engineering and, ultimately, a better life for all people. Undoubtedly the cost of space research is not too exorbitant a price to pay for this.



2. MOON FABLES



The moon is second only to the sun in the earth's sky, and it is hardly surprising that from time immemorial people have associated it with many superstitions, beliefs and supernatural force with it. Many are the legends which different peoples tell about the moon. In African Bushman folklore it is a living being from which the sun in anger cuts off piece by piece with its rays—and the moon wanes. She entreats the sun to spare her for her children's sake. The sun relents, and the new moon waxes until the infuriated luminary attacks her again.

According to a legend of the ancient inhabitants of the country around the sources of the Nile, there was a time when people were immortal. Realization of this made them arrogant and they refused to offer sacrifices to their gods.

The great Wizard who presided over their fate brought the heavenly firmament down on their heads, destroying them all. He then sent a man and woman to earth to populate it anew. They had tails. The woman bore a son and two daughters, from whom issued Chameleon and Luna. Chameleon grew up to have a malicious and perfidious character and he quarrelled violently with his sister. Seeing this the Wizard took Luna up to his home in the sky from where she looks down on earth. But he made her wax and wane so that she should not forget her terrestrial origin. When she is almost gone she crosses the horizon from east to west in two days, turning from a morning into an evening luminary, and appears small in the west after her long journey. The sun feared that Luna would become his rival and he burned her with his rays. We can see the scars on her face to this day. Meanwhile Chameleon's progeny populated the earth. Their tails disappeared, and their skin grew dark under the burning rays of the sun. People with tails still live in the heavens. They have large herds of cattle, and the great Wizard sends them out at night to guard the stars. Venus, according to this legend, is Luna's lover.

To some peoples the brilliant nocturnal disk with its dark "eye-sockets" looked like a human head and they regarded it as a mysterious all-seeing being. Others considered the moon to be a young man who visited women at night. To the ancient Greeks and Romans the moon was a young goddess variously known as Artemis, Diana and Selene. Primitive people kept count of time according to the phases of the moon,

and they might say that some event happened "five or six moons ago". Diogenes Laertius wrote in the third century A. D. that the Egyptians had records of 373 solar and 832 lunar eclipses. It is estimated that such a record must have covered at least 10,000 years. The moon has been a symbol of eternal renewal and some peoples associate it with the cult of water.

The Ancient Greek philosopher Aristotle claimed there was a definite connection between the moon and the state of a man's blood. From being a mythical and magic symbol the moon became a poetic image, and Pindar saw it as a nocturnal eye, while Horace called it the Queen of Silence. Many centuries before the telescope offered definite proof that the moon was a celestial body the idea was voiced by the ancient Greek philosophers Democritus, Anaxagoras and Pythagoras. Plato and Cicero imagined journeys to the moon, and Plutarch defined it as "a heavenly body whose surface is covered with deep crevasses and fissures". Science was later to prove him right.

The first man to look at the moon through a telescope was Galileo. In 1610 he described what he saw in one of the most exciting scientific works ever written:

The surface of the Moon is not perfectly smooth, free from inequalities and exactly spherical, as a large school of philosophers considers with regard to the moon and other heavenly bodies, but on the contrary, it is full of inequalities, uneven, full of hollows and protuberances, just like the surface of the Earth itself, which is varied everywhere by lofty mountains and deep valleys.

Concerning the possibility of life on the moon, Galileo refrained from committing himself

either way. Johannes Kepler, Galileo's contemporary and friend, gave a description of conditions and life on the moon which guided many an author for two and a half centuries. According to Kepler, life existed on the moon, though, of course, in forms unknown on earth. He visualized lunar plants and animals as fast-growing giants which attained huge proportions in the course of the lunar day and perished at night:

Some of them crawl about, others have wings, but they are all serpent-like.

In spite of his fantastic ideas about lunar inhabitants, Kepler's description of what a man could expect to see on the moon was better than that of any other author a hundred years after him. In 1833, the English astronomer John Herschel published a sensational account of moon-scape scenes which he claimed to have observed: green valleys, blue rocks, blue lakes rimmed with white-sand beaches, and rivers rushing down deep gorges. When H. G. Wells wrote his book, *The First Men in the Moon*, he confronted his heroes, Bedford and Cavor, with a world in which beauty and horror mixed together. Four hundred years ago Rablais wrote that some people thought the moon to be made of green cheese. Even in the twentieth century, one astronomer reported that he had observed huge swarms of insects crawling in lunar craters and claimed that the moon's surface is covered with a fibrous substance.

✱

✱

3. BIRTH OF A DREAM

✱

✱

✱

✱

✱

✱

✱

One ancient Indian manuscript claims that people had travelled in outer space a million years before it was written. Many old legends and tales tell of flights to the moon with the help of all manner of propulsion systems, from flocks of trained swans to the suction force of great whirlwinds. After Blaise Pascal established that the pressure of the air drops rapidly with height dreamers had to devise some means of travelling through empty space. Cyrano de Bergerac suggested, in 1649 and again in 1652, a variety of fantastic ways to reach the moon: bottles in which the evaporation of dew would create the necessary lift force; pieces of magnetic iron thrown upwards to attract an iron chariot; bundles of fireworks rockets.

Isaac Newton, who discovered the law of gravitation, also considered the possibility of space

flight and developed a mathematical formula of the initial velocity required for a vehicle to escape the earth's gravitational pull. He found that a speed of 11 kilometres per second (6.8 m/sec) was necessary for a projectile to escape from the earth for good. As the frontiers of knowledge expanded new difficulties and new possibilities presented themselves to enthusiasts of interplanetary flight. The moon was an obvious first target.

Jules Verne, in his book *From the Earth to the Moon*, published in 1865, tried to get round the problem of a suitable propulsion system by resorting to a giant cannon dug into the earth, a mode of travel which might be possible, provided the passengers could withstand the shock of almost instantaneous acceleration and the temperature generated by the friction of the atmosphere. H. G. Well's *First Men in the Moon* coated their vehicle with "cavorite", a material impenetrable to the forces of gravity.

Today we know that it is impossible to use a cannon to shoot a projectile into space against the earth's gravitational field and through its dense atmosphere. On the moon, where there is no atmosphere and gravity is small, a cannon might be able to shoot a projectile to the earth.

The first man to develop the theoretical foundations of space flight was K. E. Tsiolkovsky whom we justly regard as the founder of the science of astronautics. As far back as 1903, he realized the important fact that a rocket does not need an atmosphere to propel it and can overcome the earth's gravity and atmospheric drag by judicious manipulation of its acceleration.

Some people ask why Tsiolkovsky is regarded as the "father of space flight", and not Jules Verne, who dreamed of travel to the moon long before him. The simple reason is that Jules Verne's was the fantasy of an artist. Tsiolkovsky developed his dreams into a scientific theory. Tsiolkovsky's rocket, not Jules Verne's cannon, opened up the road into outer space.

Out of the great galaxy of Russian scientists who enriched science with discoveries of world importance there are many whose works have a direct bearing on interplanetary flight and space research. The first to suggest the use of a reaction propulsion system for manned flight was N. Kibalchich, scientist and revolutionary, who in 1881 made his drawing of a rocket-propelled projectile in a cell of the Fortress of Peter and Paul in St. Petersburg (Leningrad), a few days before he was executed. N. E. Zhukovsky, whom Lenin called "the father of Russian aviation", laid the theoretical foundations of aeronautics, the elder sister of astronautics. He could with equal justification be called the father of world aviation. His pupil S. A. Chaplygin developed the science of gas dynamics, and I. V. Meshchersky developed the fundamentals of the mechanics of bodies with variable mass.

Tsiolkovsky's dream of interplanetary flight turned gradually into a firm conviction of its possibility. He wrote some 700 works on the subject. In one of them we find the immortal words:

Man will not remain on earth forever, but in quest of light and space he will emerge beyond the limits of the atmosphere, at first tentatively, and later to conquer for himself the whole of the space surrounding the sun.

They are inscribed on the pedestal of a statue of Tsiolkovsky in Kaluga. And here is what the German professor Hermann Obert wrote to Tsiolkovsky:

You kindled this fire. We shall not let it die and will spare no effort to make man's greatest dream come true.¹

Similar sentiments were expressed by such pioneers of rocketry and astronautics as Homann, Lademann, Heft, Shershevsky and Ley.

After the establishment of Soviet government, a group of engineers and scientists, enthusiastic supporters of Tsiolkovsky's ideas, got together to study problems of space flight. They designed a number of working models of rockets and developed many interesting scientific ideas. In 1920 F. A. Tsander reported in Moscow on the design of a motor for an interplanetary space vehicle. The first liquid-propellant rocket motors were built early in the 1930s, and in 1933 a liquid-propellant rocket was launched. This was later followed by the SK-9 "rocket plane", tests of ramjet engines and the first flight of a fighter plane powered by a liquid-propellant engine. These achievements were crowned by the launching of Sputnik 1, the world's first artificial earth satellite, on October 4, 1957.

Characteristically enough, even then many experts proved incapable of correctly appreciating the speed with which rocket techniques and space conquest would advance. Werner von

¹ Obert's original letters are in the possession of the Tsiolkovsky Foundation of the Academy of Sciences of the U.S.S.R.

Braun, head of America's space project, declared at an astronautical conference, held shortly after Sputnik 1 went into orbit, that it would take at least five years before a space vehicle would be brought back to earth, and 10 years before a man could board such a vehicle. However, the first spaceship was brought safely back to earth in the summer of 1960, and on April 12 of the following year Yuri Gagarin became the first earthman to journey into outer space.

Similarly, after the first Soviet Lunik was launched, in the beginning of 1959, one eminent astronomer in the West declared that man would never reach the moon using a ballistic missile. Not many months passed before Lunik 2 hit the moon's surface.

—

*
* 4. WHAT WE
* KNOW ABOUT
* THE MOON
*
*
*
*
*
*
*

The moon is not a hospitable world. During the day a blinding sun heats its surface to $+120^{\circ}\text{C}$, 20 degrees above the boiling point of water. At night the hot rocks rapidly lose their accumulated heat and cool down to -150° . An approximate idea of the climate on the moon (if one can speak of such a thing) can be obtained by imagining a place on earth where the cold of the winter Arctic and the heat of the equator alternates every 15 days. The moon's surface area is not very large: 36 million square kilometres (13 million square miles); the area of the Americas is 15.5 million square miles. It would take 49 spheres like the moon to fill the volume occupied by the earth. As its mean density is lower it would take 81 moons to balance the earth. Because of its small mass, the moon's gra-

vity is only 1/6th that of the earth's, and a man weighing 150 pounds here would weigh 25 pounds there—with the same muscle power. The moon appears to have an extremely tenuous atmosphere with a density about 10^{-13} that of the terrestrial atmosphere, which corresponds to an altitude of 500 kilometres. The absence of an appreciable atmosphere is due to the moon's small gravitational attraction. Knowledge of the composition of the traces of gases at its surface will be of importance intracing its evolution.

Our knowledge of the moon can be summed up in the following "vital statistics":

Distance from the earth: Apogee, 406,670 km (252,948 mi), perigee, 356,400 km (221,513 mi). The mean distance is 1/390th the distance from the earth to the sun, and the diameter of the moon is 1/401th that of the sun.

Sidereal period (time of one revolution round the earth): 27 days 7 hours 43 minutes 11.47 seconds.

Synodic period (interval between two successive new moons): 29 days 6 hours to 29 days 19 hours 54 minutes.

Mass: 0.01228 that of the earth.

Volume: 0.0203 that of the earth.

Mean density: 0.606 that of the earth or 3.3 that of water.

Mean orbital velocity: 1.02 km/sec (0.6 mi/sec).

Albedo (fraction of total incident light reflected back by a surface): 0.07

Time required for radio waves to travel from the earth to the moon: 1.28 seconds.

This is a very incomplete list of data in the hands of selenographers today (a selenographer is a man who studies the geography of the moon), and if an astronaut had to fly to the moon today he would be much better off, geographically and cartographically, than Columbus was when he set off to discover the New World.

The visible surface of the moon is studied in great detail, and lunar atlases boast more than 35,000 named features of the relief. One of the most detailed atlases is a seven metres (23 ft) square projection, which contains a further 200,000 unnamed features.

The unaided eye can distinguish several dark spots on the face of the moon. These are vast plains called (quite wrongly) maria, or "seas" (the term was introduced by the 17th-century Italian astronomer Giovanni Riccioli, who gave them the names by which they are known to-day). In addition to these there are numerous walled circular formations (craters), peaks, valleys, clefts, domes, rills and many finer features, the more conspicuous of which were also named by Riccioli, after famous astronomers and philosophers.

The most dominating features of the moon-scape are the craters. They are seen in especially fine detail when close to the terminator, the line deviding the lighted from the dark hemisphere. Some craters appear to be the centres of systems of rays. Their nature is not known, though it has been suggested that they are surface deposits (explosion ejecta) whose brilliance is due to luminescence or phosphorescence of lunar rock exposed to the sun. On earth, the sun's ultraviolet radiation, which would be primarily responsible for such phosphorescence, is almost completely absorbed by the atmosphere. The extension of rays on the moon's surface has enabled selenographers to posit the location of some two dozen craters on the far side. (Incidentally, thanks to the phenomenon known as libration,

some 61 per cent of the moon's surface can be seen from the earth.)

Several years ago a team of Soviet astronomers under V. F. Kuprevich began to photograph the moon and other celestial bodies in the infrared region of the spectrum. The resulting pictures were much sharper than those obtained in the visual spectrum, and they presented new opportunities for studying the moon.

There are many theories of the origin of the moon. Some workers, notably Nobel Prize winner Harold Urey of the University of California, suggests that it is older than the earth; towards the end of the period of formation of the earth. the moon passed close to it and was captured. George Darwin, son of Charles Darwin, suggested some fifty years ago that the moon had been torn out of the earth by some cosmic force. He sees proof of this in the lower density of the moon, which could be explained by the fact that it had broken away from the earth's outer, and lighter, crust. Some scholars still accept this theory, although most have rejected it. Thomas Gold of Cornell University has attempted to explain the low density of the moon by assuming the existence of a thick layer of ice several hundred feet below the surface, where the temperature is uniform. Others consider the moon to be a homogeneous mixture of metallic and stone meteorites. And Gordon Macdonald of the US National Aeronautical and Space Administration (NASA) has even suggested that it might be hollow inside.

A theory widely accepted in the Soviet Union is that of Otto Schmidt, according to which the

planets and their satellites were formed in the passage of the sun through a cloud of dust and meteoric matter. As a result of mutual collisions and the accretion of dust particles in the proto-planetary cloud, centres of gravitation appeared around which the planets gradually formed. At the initial stage, when the planetary cores were surrounded by a swarm of particles, the satellites, too, began to form.

The age of the moon could be determined in the following way. Measurements of the relative abundance of radioactive elements and their decay products in meteorites indicate that the meteorites must have solidified some 4,500 million years ago. (Meteorites are mostly splinters from collisions between asteroids, which circle the sun in a wide belt between Mars and Jupiter.) It has been suggested that, before that period, the asteroids, like the earth and the moon, had melted due to heating from radioactive decay, which was much more intensive then than today. But as the moon and earth are much larger than the asteroids (the biggest one, Ceres, is only some 800 kilometres, 485 miles, in diameter), they retained their internal heat much longer.

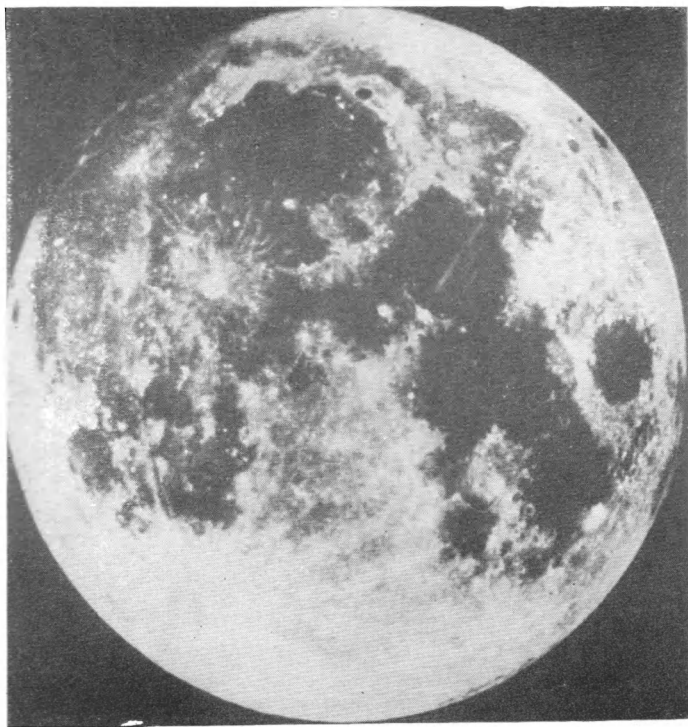
Like other celestial objects, the moon has so far been studied from the earth by visual, photographic, photometric, thermometric, spectroscopic, polarimetric and radioastronomical methods. Despite their sophistication, they have important limitations. One of the greatest handicaps for astronomical observations is the earth's atmosphere, which distorts and blurs the visual image of celestial objects, making it impossible to exploit to the full the capabilities of optical

instruments. With the help of telescopes astronomers can today observe, in both celestial hemispheres, some 1,100 stars of 5th stellar magnitude, 4,000 of 6th, 8,000 of 7th, 6,200 of 9th, 2,700,000 of 13th, 70,000,000 of 17th, and 900,000,000 of 21st magnitude. But obviously, it is a long way from detecting and counting stars and other objects to studying them and gathering data on their structures, atmospheres, ages, etc.

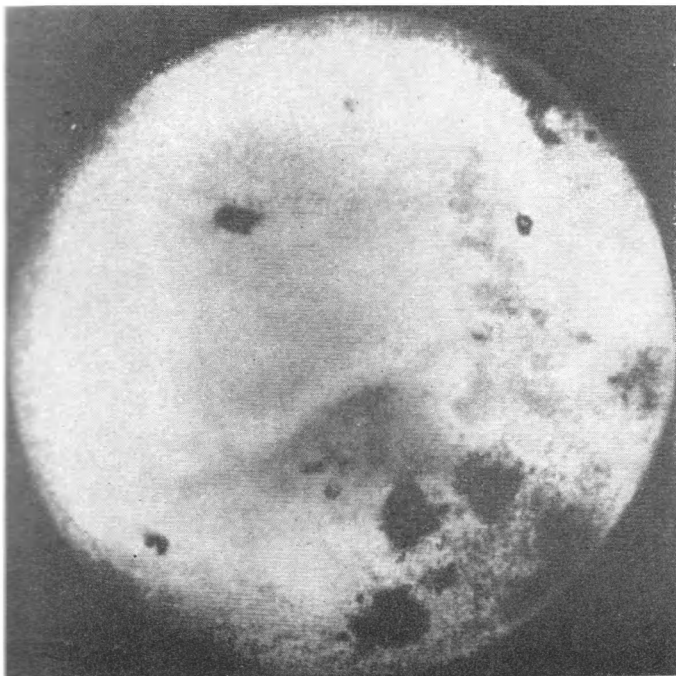
The construction of powerful transmitters, large antennae and sensitive receiving instruments has enabled scientists to bounce radar signals off Mercury, Venus, Mars and Jupiter. The purpose of these experiments was to determine the astronomical unit, which is the basic yardstick for measuring cosmic distances, to verify the rotation periods of the planets and get additional information about their surfaces. These experiments revealed an error of one-tenth of one per cent in the length of the astronomical unit. The error is not very great, to be sure, and the accuracy was more or less satisfactory for astronomical observations. It is quite unacceptable, however, for the navigation of interplanetary spaceships. The error in the distance to Venus, for example, was of the order of 50,000 kilometres (30,000 miles), which is several times the diameter of the planet. The distance from the earth to Venus at closest approach is found to be some 45 million kilometres (28 million miles), or 120 times greater than to the moon. In another experiment, the reflection of radio waves from Mercury was found to be very similar to that from the moon.



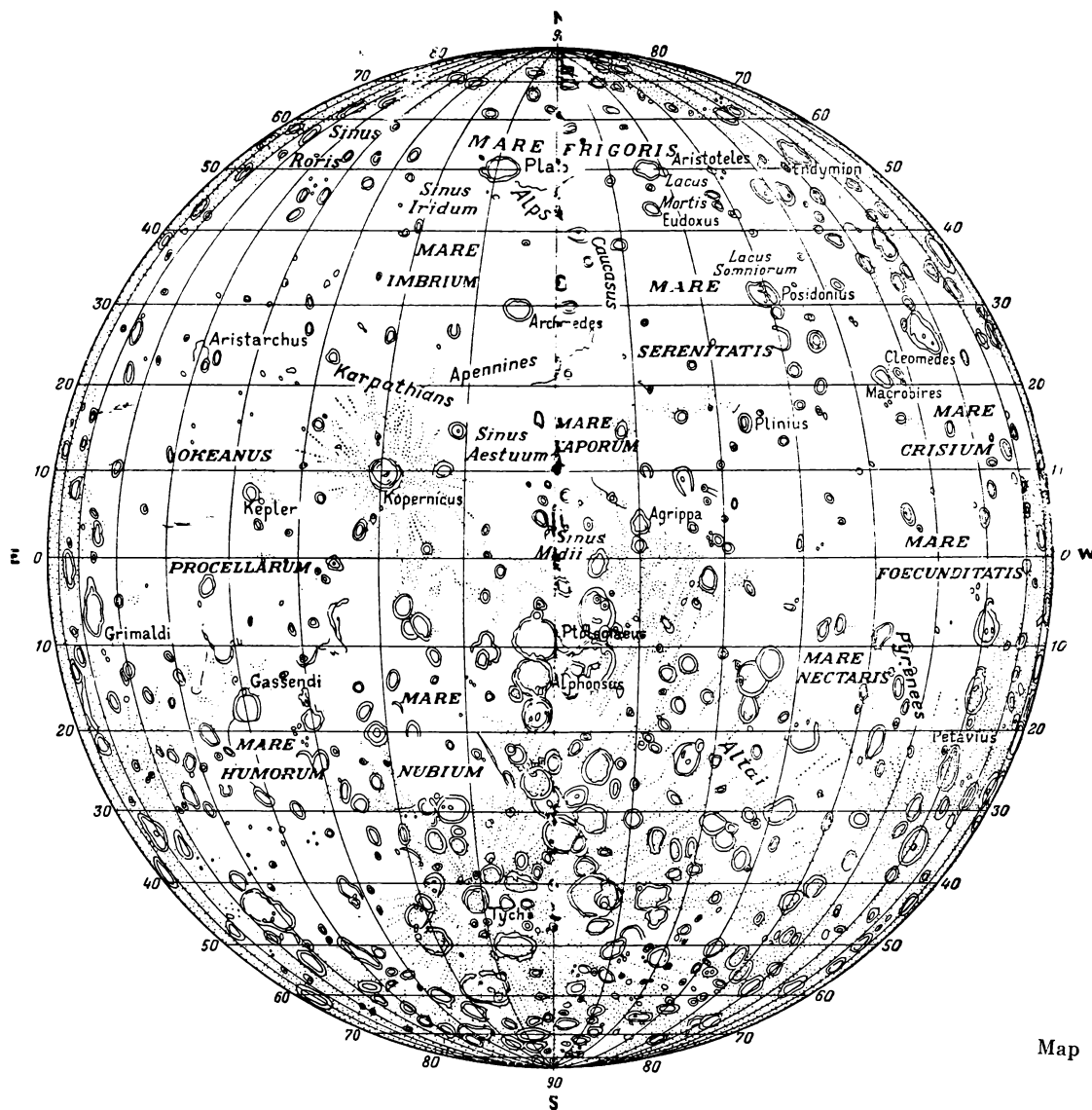
This is what the first space traveller will see when he disembarks from his ship on the moon. The picture was transmitted by the Soviet automatic station Luna 9



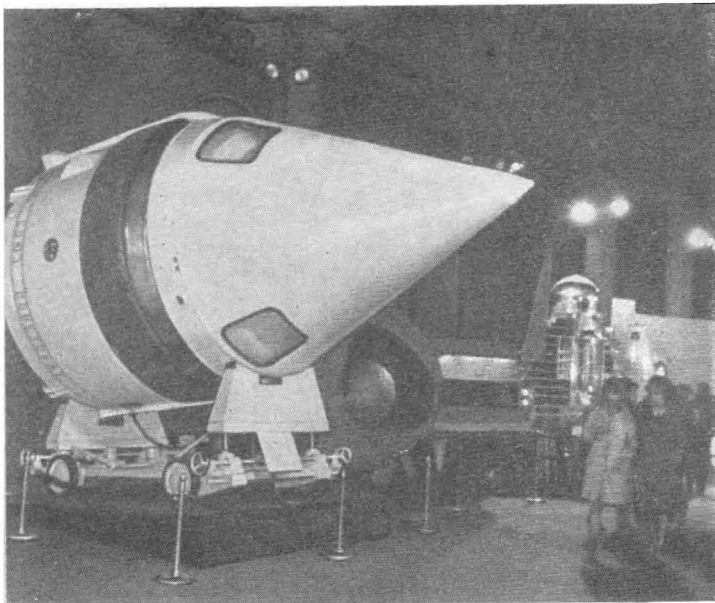
Telescopic appearance of the moon



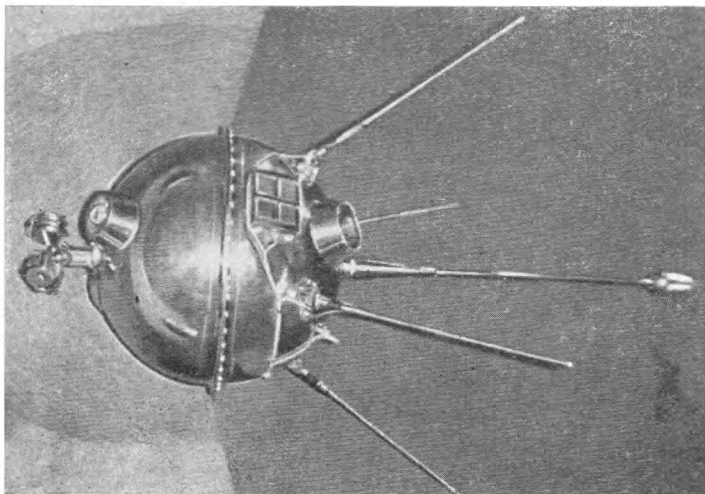
Photograph of the reverse side of the moon taken by the Soviet automatic interplanetary probe Lunik 3 in October 1959



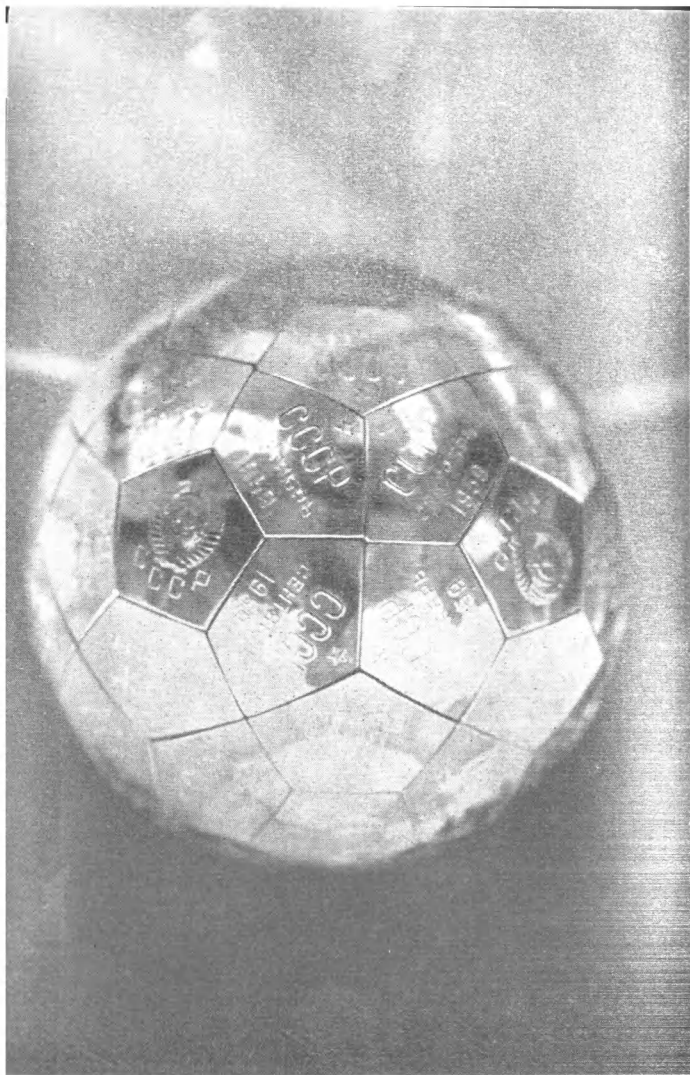
Map of the moon



Last stage of the Soviet space rocket Lunik 2 which in September 1959 made the first trip to another celestial body in human history



The automatic interplanetary probe Lunik 1 which in January 1959 measured the moon's magnetic field and the radiation level in the neighbourhood of the moon



The pennant delivered to the moon by the Soviet interplanetary probe Lunik 2 in September 1959

On November 19th and 24th, 1962, Soviet scientists carried out the first experiment in "cosmic" radio communication by bouncing signals off the planet Venus. The words "Lenin", "USSR" and "Peace" were transmitted in Morse code and picked up 4 minutes 32.7 seconds later on November 19th, and 4 minutes 44.7 seconds later on November 24th, indicating distances of 81,745,000 and 85,360,000 kilometres (50,794,000 and 53,040,000 miles), respectively.

As mentioned before, many of the arguments and hypotheses concerning the structure and history of our neighbours in the universe cannot be resolved using earth-based instruments alone. It will take on-the-spot exploration of the moon and the planets by unmanned probes and then by man himself to gain reliable knowledge of extraterrestrial conditions.

A new stage in lunar exploration of the moon began in 1959, when a Soviet automatic interplanetary station, commonly known as Lunik 3, photographed the reverse side of the moon. Soviet probes with magnetometers on board carried out measurements of the moon's magnetic field as close as 50 kilometres (30 miles) from its surface. Their findings indicate that the moon's magnetic field, if there is one at all, is at least a thousand times weaker than the earth's. This discovery, one of the first to be made entirely, by a space probe, is of great importance. It may provide a clue to the origin of the earth's magnetic field, the intensity of which, according to some scientists, is in direct proportion to the planet's speed of rotation on its axis.

✱

✱

5. HYPOTHESES AND THEORIES

✱

✱

✱

✱

✱

✱

✱

The nature of the moon's surface is of great importance to future explorers. The Soviet astronomer V. G. Fesenkov considers, on the basis of studies of variations in the brightness of surface features, that the lunar terrain is covered with fissures with vertical walls and sharp edges. Other experts think that the moon is covered with something like hardened foam which may crumble under the weight of a man. Dr. Dollfus from the Paris Observatory suggests that it may be a powdered material something like volcanic ash. Several years ago a theory was voiced according to which the dark maria are "seas" of dust which could well engulf a spaceship attempting to land there.

When Dr. James Evans of the Lincoln laboratory carried out radar studies of the moon,

he found that reflections of radio waves from its surface resemble reflections obtained by airborne radar installations from the surface of sand deserts. He concludes that in between the mountains and craters the moon is generally smooth. Some astronomers consider that there is practically no loose dust on the moon. At any great distance from new craters more than 100 metres in diameter the surface must have a structural strength at least equal to that of sand deserts, if not more. It could be packed tightly enough to crunch under one's feet and to leave hardly any track. It has also been pointed out that fissures covered with a thin crust in the lava beds of the maria may be of considerable danger to vehicles on the moon.

It is certainly not easy to choose confidently from among all the moon theories. This is hardly surprising, seeing that scientists must rely almost completely on visual observations, which have only recently been supplemented by investigations of reflected radio and intrinsic infrared radiation.

Strange as it may seem, in spite of its proximity to us, the moon is probably the most controversial object in outer space. Even those workers who agree that it is largely covered with dust differ widely as to the thickness of the layer and its origin. Thus, L. N. Radlova and G. Urey consider it to be of meteoric origin. In the moon's lifetime a layer of several centimetres could be deposited. Professor V. V. Sharonov thinks that meteorites falling on the moon eroded lunar rock, thus contributing to a dust layer of mixed indigenous and cosmic origin. Accord-

ing to his hypothesis several metres of cosmic dust should have settled on the moon. The earth, it is estimated, receives some 2,000 tons of meteoritic matter every day, which means an average rate of 2×10^{-14} gram per square centimetre per second. Fallout on the moon must evidently be less as its gravitational field is weaker, and the rate is considered to be 1 g/cm² in two million years. At this rate (which, of course, could have been much greater in the remote past) the deposition of dust in 4×10^9 years would amount to 2 kg/cm², which would give a layer several metres thick.

Some clarity was introduced into the debate during a discussion of a report by Vsevolod Troitsky at a national conference on the exploration of the moon, Mars and Venus, in December 1962, sponsored by the Sternberg Astronomical Institute in Moscow. A team of astronomers used radio waves to study the lunar surface to a depth of one metre or so and their findings indicate a light porous mass rather than a layer of dust.

The chemical properties of lunar rock are of necessity studied by optical means and compared with the optical properties of terrestrial rock. Some important work in this field has been carried out in Kharkov under Professor N.P. Barabashov, and in Leningrad by V.V. Sharonov and N.N. Sytinskaya.

However, V.S. Troitsky and his collaborators in Gorky consider the optical method to be unreliable and prefer investigations with radio waves of different length.

"On the basis of our findings," Troitsky says, "we can picture the surface of the moon as a

dismal desert undulating like a mildly choppy sea that has suddenly petrified. The monotony of the moonscape is broken only at the foot of mountains and craters, where the terrain rises and rocks are piled up."

Most workers seem to agree that travellers to the moon will not be engulfed in seas of dust and that their spaceships will land safely on a hard, crunchy soil. The English physicist Libby thinks that explorers of the moon may even find oil on the bottom of lunar craters. He bases this on the fact that paraffin wax has been discovered in some stone meteorites. The countless meteorites that have fallen on the moon's surface may have delivered substantial quantities of this "relative" of petroleum—a hypothesis voiced, incidentally, by the great Russian chemist D. I. Mendeleev a hundred years ago.

On November 3rd, 1958, and October 29th, 1959, the Soviet scientist N. A. Kozyrev observed a fluorescence of gases in the crater Alphonsus. Forty years ago changes in the colouring of the bottom of lunar craters were explained by the presence of vegetation there. One of the most ardent exponents of this idea was the American William Pickering, who conducted observations of the moon from his observatory in Jamaica, from 1919 to 1924. When moving spots were alleged to have been observed on the floors of some craters he declared that they were due to huge swarms of insects feeding on lunar vegetation. Dr. Dollfus, however, writes in one of his books that changes in colouring probably take place in areas covered with substances with varying reflecting properties.

The moon's craters are mysteries for more reasons than one. Few of them look at all like terrestrial craters of volcanic origin. On the other hand, if they were caused by the impact of large meteorites one could expect many of them to be elliptical in shape, as an average meteorite would naturally fall to the surface along a slanting trajectory. Yet most craters are circular. Professor Kozyrev thinks that most lunar craters are of volcanic origin. Dr. Eugene Shoemaker, chief of the Astrogeology Branch of the U.S. Geological Survey, is an exponent of the impact theory of crater formation. He suggests that the moon's largest crater, Mare Imbrium ("Sea of Showers"), was created by the fall of a huge meteorite, probably an asteroid which, it is estimated, must have been more than a hundred miles in diameter. The impact dug a crater more than 700 miles wide and splashed lunar material all over most of the visible side of the moon. Another crater, Copernicus, is one of the most prominent "ray" craters. The rays are bright streaks radiating out from the crater rim as if they had been splashed out, and they offer virtually irrefutable testimony in favour of the impact origin of at least this crater. The distribution pattern of matter ejected from Copernicus is remarkably like that produced in two underground nuclear explosions in the United States which left large craters. The rays, it should be noted, cast no shadows and are almost indistinguishable when the sun is low over the horizon. One of the first tasks of explorers of the moon will be to collect samples of ray material. Shoemaker considers that the meteor which created

Copernicus fell on the moon some 500 million years ago.

People often ask whether life in any form is at all possible on the moon. The origin of the kind of life familiar to us is inseparable from the presence of water. An answer to the question will therefore depend on whether there is any water on the moon. It has been estimated that generally two or three cubic kilometres (0.35-0.55 cubic miles) of water should be formed per square kilometre (0.39 square mile) of surface of a newly forming planet. What happens to this water later on in the planet's evolution is another matter. Conditions on the moon could well contribute towards the dissipation of most of its water. On the other hand, as V. F. Kuprevich of the Soviet Academy of Sciences points out, if astrophysicists are right in stating that the moon's surface layer possesses marked thermal insulation properties, one could expect to find substantial deposits of "mineral" ice at some depth. Moreover, Kuprevich does not preclude the possibility of water being found on, or rather in, the moon in liquid form. In other words, one of the essential prerequisites for the development of life, water, is probably present on the moon.

Of considerable interest are investigations of the colour of the lunar surface carried out not long ago by Soviet scientists N. P. Barabashov and A. T. Chekidra. The bright rays radiating from the crater Tycho appear to be of a reddish tint, and formations attributed to the Copernicus splash have a similar hue. Heated arguments among scientists have failed to produce a unani-

mous opinion on the structure of the moon's surface. According to the different schools of scientific thought it is largely covered with lava; or pumice, or dust, or chondritic material. The argument can evidently be resolved only by sending an expedition to the moon.

The first astronauts who return home from the moon will have many stories to interest both the expert and the inquisitive layman. They will tell us what natural phenomena caused the craters and whether the earth has ever experienced—or may experience in future—similar phenomena. They will verify Prof. Kozyrev's claim that volcanic and seismic activity takes place on the moon to this day. Automatic lunar stations will relay back to earth information on the moon's surface. Until recently we were unable to observe lunar features less than 500 (1,500 ft) metres across. Although the American Ranger probes have sent back photographs of much finer detail, many things still remain unclear and scientists continue to disagree on many important aspects of the lunar relief.

It is difficult to overestimate the importance of experiments carried out on the surface of the moon. Very many questions must be answered: What is the relative abundance of silicon and oxygen? In what proportions will iron, magnesium, aluminium, calcium and potassium be found? How much water is there in the moon's crust? How much nitrogen? What is the crystal structure of the white substance observed in rills and on the inner slopes of the rims of the craters? What is the temperature and thermal conductivity of lunar rock at various depths?

Does the moon have a magnetic field? Does seismic activity take place on the moon?

A thorough study of the moon is important not only from the point of view of getting to know it as a celestial body. For some 5,000 million years the moon has kept a continuous record of all the events taking place in the neighbourhood of the earth, a record which, thanks to the absence of an atmosphere and atmospheric erosion, has been preserved practically intact. The composition of the moon's surface layers will tell us much about the early history of the earth-moon system. In particular, it may be possible to establish whether the two bodies ever had a common envelope.

Although the moon has no atmosphere and no weather as we understand it, visiting astronauts will nevertheless look for indications of erosion. As there is no atmosphere, the sunlit side of the moon is swept by a "solar wind", a stream of gas and plasma. Although it is extremely tenuous and carries only infinitesimal quantities of matter, the solar wind must have had an erosive effect on the surface of the moon during the millions of years it has been blowing. Excavations on the moon will reveal changes that have taken place in the force and intensity of the solar wind in the past.

Another task for astronauts on the moon will be to investigate whether any traces of an atmosphere exist there. According to one theory the moon is enveloped in a thin atmosphere of atomic hydrogen, a byproduct of the "solar wind". In order to check this explorers will have to engage in on-the-spot studies of the so-called

Lyman Series in the far ultraviolet of the solar spectrum as seen on the surface of the moon.

In the course of unmanned exploration of the moon automatic seismographs will keep track of possible volcanic activity and their findings will subsequently be verified by manned teams of selenologists. One of the early expeditions to the moon will install a radio telescope as near as possible to the centre of the visible disk. A very simple radio antenna could be set up by stretching two wires intersecting at right angles. The wires, 1,000 metres long, could be shot out of a suitably designed gun, just as a harpoon with a rope tied to it is shot out of a whaling gun. The antenna would be able to pick up very low-frequency radio waves from different parts of the sky. They do not reach the earth as its atmosphere is opaque to waves of that frequency.

Another important priority will be to drill several deep wells in order to measure the flow of heat from inside the moon. Measurements of this kind will help to resolve, at least in part, some of the theories concerning its internal structure. Astronomers sounding the moon with radio telescopes operating on different frequencies have come to the conclusion that the moon must be hot at some distance below the surface. Measurements reveal that 20 metres down the temperature is 25°C higher than at the surface. Extrapolating downwards, a thermometer lowered into a well some 30 or 40 miles deep should indicate a temperature of 1,000°C. Furthermore, according to these workers, the flow of heat to the moon's surface is about the same as the flow

of heat inside the earth. Other scientists disagree and, as mentioned earlier, some theories claim that the moon is merely a huge ball of iron, stone and ice meteorites.

The first rock samples from the moon will be subjected to an exhaustive investigation. If hydrate compounds are found they may well serve as a source of water for future lunar bases. An analysis of radioactive decay will tell scientists the age of the different lunar formations. In short, information about the moon may give rise to new ideas concerning the evolution of the solar system as a whole and the earth and its evolution, in particular.

44



sity is much higher than the cosmic average and presents a real hazard to life. The origin and structure of the radiation belts are still being studied, but it is already apparent that precautionary measures must be taken to shield astronauts from them. A similar problem will be encountered in planning manned flights to other planets, which may also possess radiation belts. One way of evading the radiation belts is to launch a rocket through the polar regions.

Every once in a while spectacular eruptions and outbursts take place on the sun in which masses of ionized matter and high-energy radiation are ejected into space. Most of this radiation is made up of protons—nuclei of hydrogen—which, although they are energetic enough to penetrate a thick layer of lead, cannot pass through the lines of force of the Earth's magnetic field. Solar flares and prominences follow the variations in the sun's activity, which must be taken into account in planning space flights. Outside the protective shields of the earth's atmosphere and magnetic field solar flares will present a considerable hazard, all the more so as they are unpredictable. Flares emit radio waves which travel slightly faster than the deadly radiation, and this may be used to warn astronauts of a dangerous outburst a few minutes in advance. On the way to the moon the rocket should be oriented in such a way as to present the smallest surface possible to the sun's radiation. On the moon there will have to be an elaborate warning system so that people working on sites exposed to the sun would be able to seek shelter in the event of a sudden outburst.

The earth's atmosphere protects us from a steady bombardment by meteoritic particles of different size, usually no greater than specks of sand, though occasionally big rocks streak to earth in spectacular fireballs. The small meteors entering the atmosphere are rapidly heated by friction and produce the "shooting stars" seen so often on a dark starlit night. They burn up, disintegrate and settle on the earth in a fine dust.

The meteorite problem is further aggravated by the existence of meteor streams which appear on earth as regularly recurring, identifiable showers. Several hundred meteor streams are known to move about the sun in elliptical orbits with periods ranging from a year to 125 years and more. The dates of the maxima of these streams, which correspond to the intersection of their orbits with that of the earth, are known and spaceship launchings can be timed accordingly. Obviously, unknown meteor streams pass through many regions of space and it will be the task of rocket probes to chart their routes. Bodies belonging to the solar system, meteor streams included, travel in orbits lying in or close to the plane of the ecliptic¹. Flights outside this region would reduce the chance of encountering meteors, micrometeors and other extraterrestrial rubble, though from the point of view of power expenditure such flights would be more difficult.

¹ The ecliptic is the intersection of the plane of the earth's orbit with the celestial sphere. It can also be defined as the apparent path of the sun among the stars. The terrestrial equator is inclined to the ecliptic at an angle of $23^{\circ}27'$.

Astronauts landing on the daylight side of the moon will find its surface uncomfortably hot—some 120°C. Although the moon has no atmosphere and the heat from the ground will therefore pass to the astronaut only through the soles on his shoes, his spacesuit will be subject to the direct rays of the sun and will need to be cooled. If man sets up permanent bases and dwellings on the moon he will have to give serious consideration to the problem of cooling during the day and heating at night. Several projects for making the moon's climate less rigorous have been suggested.

One bold project has been put forward by Czechoslovak scientists with an eye on the very distant future. They propose reducing the duration of the lunar day to 24 hours by accelerating the rotation of the moon on its axis. In order to do this a ring of shafts must be sunk along the equator, their barrels suitably directed, and thermonuclear charges placed in them and exploded. The moon will start turning faster, the days will grow shorter, heating of the surface will be more uniform and the temperature differences between day and night will be more tolerable.

*
* 7. AUTOMATIC
* EXPLORERS
*
*
*
*
*
*
*
*

Manned flight to the moon is not a goal in itself and it will be undertaken only after automatic probes have carried out research sufficient to guarantee the safety of such an ambitious enterprise. It is one of the stages in the general pattern of exploration of outer space and will be undertaken when automatic instruments have accomplished their tasks. Moreover, even after men have visited the moon and other planets, automatic systems will continue to play an important part in the exploration of space and celestial bodies. This, of course, is in keeping with the general tendency of growing automation in all branches of production and life on earth.

To begin with, automatic systems will be employed largely, if not completely, in carrying out flights from the earth to the moon, landing

on the moon and returning back to earth. All stages of such a flight will be automated: take off from the earth, placing the spaceship in its trajectory to the moon, the flight itself and the landing on the moon. This applies not only to unmanned rockets with instrument payloads but to manned vehicles as well. Electronics, telemechanics and rocketry are at a sufficiently advanced stage to make it quite unnecessary for men to carry out the very difficult and responsible operation of landing on another planet. In any case, an automatic guidance system incorporating electronic altimeters, computers and other sophisticated gadgets can ensure a much safer landing with less fuel expenditure than the best pilot.

The importance of automatic pilots and control systems will be realized from the following comparison. Rockets fly at speeds of many thousands of feet per second. A nervous impulse travels along a human nerve with a speed of some 150 ft/sec. One can readily imagine the distance a rocket will have travelled by the time a human pilot takes stock of the situation, reaches a decision and starts moving to implement it. The tremendous accelerations and velocities of space flight, which require instantaneous—and correct!—decisions, make manual control virtually impossible. Journeys to the moon and back will be effected by automatons acting according to precomputed programmes subject to automatic correction in flight carried out by instruments on board or by terrestrial tracking stations. The choice of the most suitable site for landing can also be left to automatic instruments,

which would control the braking rockets as the vehicle approaches the lunar surface.

Regardless of whether the moon will be explored by automatic probes or astronauts, it is important to prevent the introduction of terrestrial gases into the lunar atmosphere, as this may lead to completely erroneous conclusions about it. For this it will be useful to park artificial satellites in orbits round the moon. As the moon's atmosphere is extremely tenuous they could be made literally to skim over the surface for indefinite periods. Their research programmes would include detailed studies of physical features of the surface by optical and radiophysical instruments. Artificial moon satellites provided with automatic measuring, photographic, television and telemetering equipment could be used for systematic observations of the moon and neighbouring space.

Exploration of the moon with the help of satellites has its drawbacks, too, of course. For one, the data they gather about the surface and interior will be indirect and therefore subject to different interpretations. Secondly, satellites cannot be used to obtain continuous measurements of variables at a given point and over long periods of time. Therefore a "soft" landing of instruments, automatic research stations and, ultimately, members of a lunar expedition, will have to be carried out if we hope to gain a true idea of the moon. An essential step towards this is the development of soft landing systems with shock-absorbing chassis and braking motors. The design of such a chassis will depend largely on our knowledge of the composition and mechani-

cal properties of lunar rock and the variations in its relief. A landing chassis can also be used as a launching pad for rockets taking samples of lunar rock back to the earth.

Mobile automatic stations landed on the moon will have to be provided with electronic equipment enabling them to negotiate the rugged lunar relief, avoid falling into crevasses and fissures and skirt steep slopes. They will be powered by semiconductor solar batteries for converting sunlight into electricity and chemical batteries for operation in the shade and at night. In time many mobile stations will be wandering all over the moon, transmitting to earth television pictures and a wealth of scientific data.

The great advances of electronics and cybernetics in recent years have resulted in the construction of automatic systems capable of controlling manufacturing processes, piloting aircraft, solving complex mathematical equations, playing chess, translating from one language into another and, of course, guiding space vehicles. They are in truth man's "eyes", "ears" and even "brains". By experts working on the human engineering problems of space flight—a branch of science which studies the interactions of the astronaut with the vehicle and equipment under his control as a single man-machine biochemical system—belong to two opposing camps as far as man's role in space conquest in general and moon exploration in particular is concerned.

One camp holds that man has nothing to do on board a spacecraft and can be completely replaced by automatons. His natural limitations, they claim, make him unsuitable for the great

variety of difficult tasks involved in controlling and manipulating the countless systems of a spaceship. The other camp assigns man the dominating role, provided the control systems take into account his psychological and physical capabilities. What does this mean?

One could say that the difficulties that faced travellers of the 15th and 16th centuries persist, in a sense, to this day. The main obstacles to the exploration of new parts of the world were lack of transportation facilities, difficulties in navigation and the natural hazards of the environment. These are essentially the same problems which face space travellers today, though on a higher level. The transportation problem, to be sure, has been more or less solved and the environment is the greatest handicap. The further man penetrates into outer space or the more complex his means of transportation, the greater the demands that must be imposed on them and the more difficult it is to embody the requirements in hardware.

This is where the human operative enters as the key element of the system. As long as man's physical capabilities are equal to a task he will generally function *better* and *more reliably* than many an automatic system. (It should be noted that in comparing a human operative with an automaton we are speaking only of man's purely physiological possibilities.)

What is meant by more reliable? The concept of reliability in engineering systems includes a number of variables. One way of expressing reliability is in terms of frequency of failure or average operational lifetime until the breakdown

of a given device, element or system. Frequency of failures is a function of, among other things, the number of elements in a system and environmental factors. Each element has a failure probability of its own which affects the overall failure probability of the system. Hence complexity naturally involves lower reliability. Scientists have been tackling the problem for years. Rockets, communication systems, radar units, etc., are useless if they do not conform to a minimum limit of reliability. A system which cannot be counted upon to function correctly ten times out of ten is far from perfect. An ultimate solution of this problem is still a long way off, and the two main technological reasons for incorporating a human operative in a spaceship guidance system is his reliability and universality.

How does a human operative contribute to greater reliability? Let us trace the stages of a flight following take-off, assuming that the problem of ensuring suitable living conditions in distant space travel has been solved. For an artificial satellite these stages may be: cut-off of the carrier-rocket motor, ballistic (coasting) flight, injection of the satellite into orbit, attitude control of the satellite, observation and communications, alteration of the orbit, and re-entry. It is essential to keep the velocity and other parameters as close as possible to the computed values if a satellite is to be placed in its required orbit or a rocket launched on a correct course to the moon.

A man controlling an automatic guidance system can considerably facilitate correct orbiting

by carrying out fine adjustment of the flight systems. This means that precision requirements for the automatic systems need not be so rigorous and equipment design can be considerably simplified.

In the case of landing on the moon, a pilot could control the approach velocity with great accuracy. He could also ensure additional control flexibility by adjusting the automatic operation. Attitude control of a rocket in flight by a human operative simplifies the system considerably. In communication systems, where frequency modulation and amplification control are usually automatic, a human operative can look after the work of the automatic systems and select the required information. This can contribute to the reliability of transmission of information earthwards.

In carrying out observations a man can take a wider view of the observed phenomena and analyze them more deeply. He can alter the operational programmes of automatic systems so as to yield the maximum of information. Programme changes in automatic devices usually require complex control systems to determine the necessity of introducing new operating regimes. Such systems are entirely feasible, but they occupy space and add to the payload of a rocket. When there are several modes of operation and a simple switching sequence is involved it pays to entrust the controls to a human operative.

Man can contribute further to the reliability of a system because, besides checking its operation, he can also repair it if necessary. Electronic equipment which may have a comparative-

ly short average lifetime can thus be made to function for long periods.

As far as "universality" is concerned, no machine can at present compare with man. He has a vast memory capacity, that is, in the language of computer techniques, an ability to store a large amount of information with a minimum of programming. He can alter his conclusions, a quality which serves as a kind of information filter. Automatic systems are incapable of effectively screening the great flood of data which will inevitably accompany space flight. A man, therefore, ensures a more efficient and useful information supply. As matters stand today, electronic systems and computers can fill only the elementary blanks in our knowledge. Only man can perceive new problems and determine the way to solve them. For this he must see outer space for himself.

Man also possesses much greater "resolving power" than machines. That is to say, he responds much more quickly and correctly to complex situations and can take on-the-spot decisions that have not been anticipated by advance programming. All these qualities make his presence in a space vehicle essential if we are to obtain the maximum possible information out of our space expeditions.

On the other hand, of course, these arguments in favour of manned space flight only have any meaning if the problem of ensuring living and working conditions out there is solved. This necessity has given tremendous impetus to the branches of medicine that study the living process in outer space, the effects of conditions there

on bodily functions and the possibility of life outside the earth, which are today combined under the heading of "space medicine".

Much information concerning living conditions in spaceships has been gained from the manned flights carried out so far. We know that a man can withstand without detriment to his health the loads which must be endured during a flight to the moon. The flights of Andrian Nikolayev and Pavel Popovich, and then of Valeri Bykovsky and Valentina Tereshkova demonstrated that space flight conditions can be endured for several days without deterioration of working ability. The Soviet cosmonauts felt well in their prolonged flights, and no disturbances of the physiological functions of their bodies were observed. The indications are that, as far as space medicine is concerned, a manned flight to the moon is feasible today.

An important aspect of space programmes is our ability to provide motors capable of launching rockets on their missions. The motors necessary for taking a crew of astronauts to the moon, and even to Mars and Venus, are now available. The efforts of scientists and engineers are primarily concentrated on developing systems capable of providing bearable living and working conditions for men in a closed ecological system. This is absolutely essential for missions which will last many weeks. Today such systems are adapted to human physiology in its present stage of evolution. However, one should not rule out the possibility of changing the human organism so that it may adapt much better to the conditions of outer space. The idea of such an evolutionary

change has been treated by science-fiction authors. The time is not far off when astrobiologists will tackle it in practical terms.

Manned flight to the moon involves technological difficulties of at least one order of magnitude higher than those of launching an automatic probe. It introduces many problems which lie outside the domain of engineering. In such an enterprise engineers must work in collaboration with physiologists, psychologists and biologists specializing in the young science of space medicine. They must evaluate the environment in which man will find himself on the way to and on the moon. The engineer's task will be to provide conditions under which the organism can function normally.

Finally, interplanetary flight, notably manned flights around and to the moon, involve limitations of a navigational character. These include the mutual positions of the earth and moon in their orbits and on their axes, which must be such that earthbound tracking stations could ensure effective control of a space vehicle. A rocket will evidently not be launched on days when the earth is passing through meteor streams or close to comet orbits.

To sum up, before distant unmanned and manned space flights are undertaken a great many problems must be solved. In the initial stages man will be in a position comparable to that of the discoverers of new lands in ancient and medieval times. He will face a multitude of hazards: storms, uncharted reefs and unknown currents as represented by solar flares, meteor streams, radiation belts and cosmic rays, plus great ac-

celeration loads ("G loads") and weightlessness. We are confident that man will soon overcome all these obstacles as he advances into space. As to the sceptics who still question the possibility of interplanetary flight to near and distant goals, we could answer them in the words of K. E. Tsiolkovsky:

There was a time, not so distant, when even the most famous scientists and thinkers scoffed at the idea of man ever getting to know the composition of heavenly bodies. This time has gone. I think that today the idea of a closer, direct exploration of the universe must seem even more preposterous. To set foot on the soil of asteroids, pick up a stone from the moon, establish moving stations in the ether, create inhabited rings around the earth, moon and sun, observe Mars from a distance of several tens of miles, land on its satellites and on its very surface—what, it would seem, could be more wild an idea. However, when reaction-propulsion devices come into use they will usher in a new and great era in astronomy: an epoch of closer scrutiny of the sky. Does not the frightening great force of gravitation intimidate us more than it warrants?

We see nothing remarkable in a cannon ball being shot with a speed of 2 km/sec. Why then should we be dismayed by the prospect of a projectile flying with a speed of 16 km/sec and receding forever from the solar system into the depths of the universe, overcoming the force of gravity of the earth, the sun and its whole system? Is the distance between the numbers 2 and 16 so great? The one is only 8 times greater than the other.

If a unit velocity is possible, why should 8 such units be impossible? Does not everything progress and advance with staggering speed? Not long ago our grandfathers considered travel at ten miles an hour to be beyond the realms of imagination. Today automobiles travel at 100-200 kilometres an hour, that is, 20 times faster than people travelled in Newton's time. Is it long since it seemed decidedly strange to use any force other than that of muscles, wind and water? One could continue in this vein endlessly!

*
* 8. LEAVING
* THE EARTH
*
*
*
*
*
*
*
*

For a spaceship to leave the earth and embark on a journey to the moon it must overcome the earth's gravitational pull. This requires an expenditure of energy. By the time a rocket passes through the earth's atmosphere its store of kinetic energy must be equal to the work that has to be done to overcome the earth's gravity, and is equal to the work done in lifting a body of the same weight in the earth's gravitational field to a height of one terrestrial radius. The earth's radius is 6,378 kilometres. Hence, for a rocket to escape the earth's gravity its motors must do 6,378,000 kilogram-metres of work per every kilogram of the rocket's weight at the surface of the earth. The last stage of the Soviet Lunik 2, launched in September 1959, weighed 1.511 kg. Therefore the work done in overcoming

the force of gravity was almost 10,000 million kg-m. This is a tremendous amount of work. A man lifting loads eight hours a day would have to work 1,000 years to perform that amount of work.

According to Newton's law of universal gravitation, all bodies are attracted to one another with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between their centres. The force with which bodies are attracted to the earth is conventionally called their weight.

It follows from the law of gravitation that when a body of constant mass is lifted above the surface of the earth its weight decreases. At an altitude equal to one terrestrial radius a body is four times lighter than at the surface as it is twice as far from the centre. Double the altitude and the body is nine times lighter than at the surface (because it is three times farther from the centre). This inverse dependence of gravity on distance means that the effects of gravity diminish rapidly as the rocket speeds away from the earth.

Then, of course, as it approaches the moon the latter's gravitational attraction comes into play and the rocket starts to fall towards it, accelerating until it attains the speed necessary for taking off from the moon, 2.4 km/sec (1.4 mi/sec). This is the so-called escape velocity. It is different for different planets: 5 km/sec (3.1 mi/sec) for Mars, 10.3 km/sec (6.4 mi/sec) for Venus, 36.7 km/sec (22.8 mi/sec) for Saturn, and 60.8 km/sec (37.7 mi/sec) for Jupiter,

For a rocket to travel from the earth to the moon and back it must first accelerate to 11.2 km/sec (7.0 mi/sec) (not taking into account the additional speed necessary to overcome the drag of the atmosphere); on approaching the moon's surface it must slow down from 2.4 km/sec to zero. Taking off from the moon it must accelerate to 2.4 km/sec, and to land on the earth it must decelerate from 11.2 km/sec to zero. The sum of all these velocities is called the characteristic velocity. From the characteristic velocity one can calculate the energy required to carry out a round trip, and hence the reserve of fuel to be taken on board the rocket. For a round trip to the moon the characteristic velocity is 27.2 km/sec (16.8 mi/sec).

It should be noted, however, that in actual fact the calculations cannot be reduced to such a simple summing of velocities. Thus, if the rocket attains a velocity of 11 km/sec it will travel 200,000 kilometres (120,000 miles) from the earth, more than half the distance to the moon. Still, it will not overcome the earth's gravity and will be pulled back into an elliptical orbit. A further slight increase in velocity has a marked effect on the rocket's path, and at 11.1 km/sec its elliptical trajectory carries it out 400,000 km (250,000 mi) from the earth, intersecting the moon's orbit. In other words, the minimum velocity needed to reach the moon is 11.1 km/sec, slightly less than the escape velocity but sufficient for the apogee of the rocket's orbit to reach the moon's orbit. If the moon happens to be on the opposite side of its orbit when the rocket comes up, the rocket will continue to swing

up and down around the earth until it either meets the moon or is retarded by the earth's atmosphere and falls.

If the rocket's velocity is increased by another 0.1 km/sec to 11.2 km/sec it will follow a parabolic trajectory and escape the earth's gravity forever. At 16.7 km/sec (10.7 mi/sec) it can overcome the gravitational attraction of the sun.

The foregoing discourse was based on the assumption that the rocket attains the required velocity instantaneously. This, of course, never happens, and acceleration takes some time. While it is accelerating a rocket climbs several hundreds or thousands of kilometres, and the higher it climbs the smaller the ultimate velocity needed to overcome the earth's gravity: 11.0 km/sec at an altitude of 200 km, 10.4 km/sec at 1,000 km, 8 km/sec at 6,000 km. If the rocket flies one-tenth of the distance to the moon (40,000 km) with working motors, the necessary speed required for it to continue its flight is only 4.2 km/sec.

Hitting the moon in the absence of systems for correcting the rocket's flight is not such an easy task as it might seem to be. All the parameters of the trajectory and motion must be adhered to within fine limits, and even small deviations may reduce the results of a mission to nought. A departure from the calculated velocity by only 1 m/sec, or 0.01 per cent of the final velocity, shifts the impact point on the moon by 250 km. A deviation of the velocity vector by one minute of arc from the calculated direction will cause a shift in the point of impact by 200 km. Other factors affecting the im-

point area are the coordinates of the point at which the motor is switched off and the timing of the blast-off; an error of 10 seconds in the countdown displaces the impact area by 200 km. These distances might not appear to be very great. But the radius of the moon is only 1,740 km, and for a rocket to hit it at all the errors in the velocity must not exceed several metres per second and deviations of the velocity vector must be not more than one-tenth of one degree. To achieve this is not a simple matter.

Future travellers to other planets will obviously have to take plenty of luggage with them. This "useful cargo", which includes instruments, supplies, etc., plus the passengers and the space capsule itself, is referred to as the "payload". An important characteristic of a rocket's performance is its so-called mass ratio, which is the ratio of the take-off mass of the rocket to its payload. An analysis of many space-projects indicates that to place a payload in orbit the total weight of the carrier rocket on the launching pad must be equivalent to some 200 tons per ton of payload. For example, according to a much-publicized project of America's "space wizard" Werner von Braun, a 30-ton payload is injected into a fairly low-lying orbit by a rocket with a take-off weight of 6,400 tons (and a thrust of 12,800 tons). Another project, due to Ehricke, envisages a 5,000 ton rocket placing 25 tons into a circular orbit. (The mass ratio of 1:200 is applicable only to carrier rockets designed for launching heavy satellites. In the case of small satellites the ratio is much higher. For example, the American Vanguard

rocket system for launching a 20-pound satellite weighed more than 10 tons, or 1,000 times more than the payload.)

In considering the power expenditure needed to deliver a mission to the moon, a mass ratio of 1:200 can be assumed. The thrust of a rocket's motors must be twice its take-off weight. Hence, in order to lift one ton of payload into outer space the rocket motors must develop a thrust of 400 tons.

The performance of a rocket motor is generally characterized by its thrust. The theory of rocket propulsion states that a rocket motor's thrust is independent of its flight speed. On the other hand, the rate at which a propulsion system does useful work, its so-called thrust power, is proportional to the rocket's flight speed. In the projects mentioned above, the first-stage engines are used to accelerate the system to 2-3 km/sec. Assuming the lesser value, 2 km/sec, one finds that an engine with a thrust of 400 tons develops 10 million horsepower. Hence, to lift a payload of 10 tons into outer space the engine must develop 100 million horsepower. This is a tremendous quantity, equivalent to the power of some thirty or more large hydroelectric stations. The obvious question is, how is a rocket to develop such energies?

Energy is produced by fuel, which may be liquid, solid or gaseous. A common requirement of all fuels is a high heat of combustion, or heat value (which is the heat generated in the burning of a unit weight of fuel). The more intense the heat generated in the combustion chamber the greater the kinetic energy of the gas jet ex-

hausted through the nozzle, and the higher the velocity of the jet (known as the exhaust velocity) the greater the thrust. The reserve of fuel in a rocket's tanks to ensure the success of an interplanetary mission is given by Tsiolkovsky's formula. Developed as far back as the 1890s, it translates the complex physical phenomena of interplanetary rocket flight into the strict and precise language of mathematics, showing how a rocket's velocity is dependent on the quantity of burnt fuel and the exhaust velocity. The formula has the form

$$V = V_j \log \left(1 + \frac{M_f}{M_r} \right),$$

where V is the velocity of the rocket, V_j is the exhaust velocity, M_f is the mass of the fuel, and M_r is the mass of the rest of the rocket (called the all-burnt mass).

From the formula it follows, firstly, that the velocity attained by the rocket is the higher the higher the exhaust velocity and the ratio of the mass of the fuel to the all-burnt mass.

A second important conclusion is that, as a rocket's flight velocity is dependent on the *ratio* of fuel to all-burnt mass, and not just on the *amount* of fuel, it is possible in principle to build rockets of any size designed to attain any required velocity.

Suppose that the ratio $\frac{M_f}{M_r} = 3$, that is, the fuel weighs three times more than the rocket and payload, which is perfectly feasible. With known fuels, however, the formula gives a maximum final velocity of only 7,880 m/sec. which is not

enough to place a rocket in orbit around the earth. If the ratio is increased to 6, which means that fuel accounts for 86 per cent of the rocket's total weight, the final velocity is 11,100 m/sec, which is sufficient to reach the moon. Assuming an exhaust velocity of 2,400 m/sec, a rocket will attain the escape velocity of 11,200 m/sec only if the initial weight of the fuel is 105 times that of the rocket and payload. It is virtually impossible to build a vehicle complete with engines, guidance systems, payload and tanks in which this ratio could be achieved. With such a fuel the construction of a rocket to reach the moon and come back to earth would be inconceivable: taking into account the energy needed to overcome the drag of the atmosphere, a rocket powered by a propellant with the suggested exhaust velocity would have to use up 10,000 times more fuel than its total weight.

There are two ways of overcoming these difficulties. One is to develop fuels with high heats of combustion.¹ The other is to improve the engines and increase their efficiency. The purpose of either method is to increase the exhaust velocity, with a corresponding improvement in performance. Thus, for example, if the exhaust velocity is increased by 300 m/sec to 2,700 m/sec, 1/3rd less fuel is needed to reach the moon.

¹ For this a fuel must have a high calorific value so as to increase the amount of heat produced by the combustion of one kilogram of fuel in the motor. All other conditions being equal, the exhaust velocity increases as the square root of the heat of combustion: for the exhaust velocity to double the heat of combustion must be four times higher.

A further increase in motor efficiency can yield considerable reductions in required fuel reserves, yet it is not enough to achieve our goal. Estimates stubbornly reveal that at the present stage of rocket techniques the amount of fuel necessary to engage in distant space flight is too great for a rocket's tanks. This is where the idea of "rocket trains" comes in handy.

This remarkable idea was first put forward by K. E. Tsiolkovsky. He suggested that several rockets be mounted one on top of another. In the initial take-off, the motors of the first-stage rocket function. When the fuel burns out it is jettisoned and the second-stage motor starts working. The procedure continues, each stage additionally accelerating the system to the velocity required for interplanetary travel. But evidently, if a rocket is to land on another planet and then take off again for the earth it must have several more stages. The question thus arises: how many stages must a space vehicle have, and how does the number of stages affect the necessary expenditure of fuel and the overall take-off weight of a rocket?

Supposing our rocket must deliver a capsule weighing one ton to the moon. Our motors and fuel ensure an exhaust velocity of 3,000 m/sec. In a single-stage rocket the weight of the fuel would have to be 60 times that of the rocket, a technologically impossible task. What happens in the case of a multi-stage rocket in which fuel accounts for 90 per cent of the weight of each stage? We find that the launching weight of a two-stage rocket must be 848 tons. For a three-stage rocket it is only 185 tons! A four-stage

rocket for the same mission would weigh 140 tons, a five-stage rocket, 124 tons, and a six-stage rocket, 116 tons.

We see that the greater the number of stages in a rocket the less its total weight for a given payload. Conversely, for a given launching weight, a rocket with more stages can deliver a bigger payload. This is explained by the fact that a multi-stage rocket discards the fuel tanks as they are emptied, thus getting rid of useless weight. And the faster the flight weight of the rocket decreases the faster the required thrust decreases, hence the lower the expenditure of fuel. All this contributes to the reduction of the reserves of propellant and oxidizer, the size and weight of the fuel tanks and the overall weight of the rocket system.

Evidently, this reduction in the weight of a "rocket train" holds only if the change in the number of stages does not affect the structural characteristic of the system, that is the relative weight of different structures in the total weight of a stage. In practice an increase in the number of stages may mean an increase in the weight of the motors, jettisoning systems, etc. A reduction in the number of stages may require an increase in tank size. Therefore the optimum number of rocket stages and their relative sizes must be chosen depending on the mission and the tasks that are to be accomplished.



* 9. ROCKET * ENGINES



The development of rocket engine design has made possible the attainment of cosmic velocities. Here is a list of the basic types of propulsion systems and the approximate velocities that they can achieve:

Reciprocating propeller engines	up to 600 km/hr
Turboprop engines	up to 800 km/hr
Turbojet engines	up to 2,000 km/hr
Ramjet engines	up to 6,000 km/hr
Solid-propellant rocket motors	up to 28,000 km/hr
Liquid-propellant rocket motors	up to 50,000 km/hr
Thermal nuclear rocket motors	up to 100,000 km/hr
Electrical ion rocket motors	up to 500,000 km/hr
Photon rockets	up to the speed of light

Obviously, the development of propulsion systems is crucial for space flight. The first manned flights were carried out in rockets using chemical propellants. The energy expenditure per unit of thrust is considerable in these systems. The Soviet Vostok manned orbital spaceships were launched with the help of rockets whose motors developed a net horsepower of 20 millions, seven times the capacity of some of the world's biggest hydroelectric stations.

A comparative evaluation of different systems and the choice of optimum parameters involve many factors, some of which are still very hypothetical. It is therefore hard to say today what type of propulsion system is most suitable for interplanetary flight. Future multi-stage vehicles may possibly be equipped with several types of systems for use in different phases of the flight. As mentioned before, take-off from and landing on planets require considerable acceleration (retardation is, of course, negative acceleration). The development of new fuels for liquid-propellant rockets will make them suitable for most of the more immediate tasks of space flight. In fact, existing propulsion systems are already suitable for flights to and around the moon, Mercury, Venus and Mars. With a multi-stage system it is theoretically possible to reach Jupiter and Saturn, but such systems are too inefficient for journeys to Neptune and Pluto, to say nothing of leaving the solar system.

Theoretically there are no limitations to the size of liquid-propellant motors, and they can be designed in a great variety of forms and types, with thrusts ranging from several kilo-

grams to many tons. They can develop considerable acceleration and provide good manoeuvrability in outer space. On the other hand, they possess some important drawbacks, notably short lifetime. This is due largely to the cooling problem. As mentioned before, the greater the heat output in the combustion chamber, the greater the kinetic energy of the exhaust gases and the greater the thrust. But today the use of many highly calorific fuels is restricted by temperature limitations in the combustion chamber. They can be overcome by producing new highly refractory materials and improving methods of cooling. Another shortcoming of liquid-propellant motors is the need to carry a store of oxidizer. This, of course, takes up space and adds to the weight problem.

“Conventional” rocket motors operating on chemical propellants burn fuel very quickly. This is useful when a rocket has to accelerate rapidly in order to overcome the earth’s gravity and atmospheric drag. But in outer space, in the absence of an atmosphere, it is possible to attain velocities of hundreds of thousands of kilometres an hour with a very small thrust and a correspondingly small expenditure of fuel. That is why engineers are hard at work on propulsion systems based on entirely new principles.

There is the very interesting possibility of utilizing nuclear energy for rocket propulsion. Nuclear fuels have heat values millions of times greater than conventional chemical fuels. The heat output in the decay of one kilogram of uranium-235, for example, is 16.7×10^{12} calories. In

nuclear propulsion systems the reaction force can be obtained from the ejection of a "working substance" (ammonia, helium or hydrogen) heated to high temperatures by the radioactive decay of uranium in nuclear reactor. The efficiency of such an installation is restricted only by the maximum temperature which the reactor can withstand. In principle, the specific thrust of a nuclear propulsion rocket may be double or triple that of a chemical fuel rocket while its mass ratio and initial weight would be smaller.

Another source of free energy, in the form of dissociated atoms of oxygen and nitrogen, is found in the upper atmosphere. It is estimated that at altitudes above 80 kilometres the concentration of free radicals due to solar radiation is sufficient to maintain the velocity of an orbital vehicle against the atmospheric drag. The principle of operation of such a propulsion system is as follows. If the free radicals of nitrogen and oxygen are in some way made to recombine into molecules, considerable energy is generated. It is estimated that at an altitude of 100 kilometres an energy output of one calory per cubic metre of air can be obtained. Gold possesses the property of facilitating the recombination of oxygen atoms into molecules. If atmospheric oxygen is blown through a gilded pipe the temperature inside increases sharply. As a result the oxygen is ejected at a higher speed, creating a thrust. In other words, a gilded pipe operates like a ramjet engine that does not need fuel to run it. Additional thrust can be obtained if methods are developed for "freezing" and storing free radicals.

Of external energy sources, potentially the most promising for space flight is sunlight, which pervades the whole of the solar system, its intensity varying inversely as the square of the distance from the sun. At the distance of the earth's orbit it is 1,400 watts per square metre of surface perpendicular to the rays. Men have long dreamed of utilizing the freely available energy of the sun, and in some regions sunlight is used to heat water, melt metals and generate electricity. Solar batteries are installed on artificial earth satellites and space probes. Systems of lenses could be used to gather sunbeams and heat the mass carrier of a rocket motor. This system would yield a small thrust and acceleration, but operating over very long periods of time, and it would be adequate for powering interplanetary craft.

At present thermal propulsion nuclear rockets and electrical propulsion ion rockets are in the development stage. The former employ thermodynamic processes similar to those that take place in chemical fuel rockets, and the working gas is heated by nuclear power. Specific fuel consumption could be of the order of 300 grams per second per ton of thrust. In an ion rocket electrically charged matter is accelerated in an electric field without heating, and the specific fuel consumption is estimated at some 10 grams per second per ton of thrust.

Motors based on this principle were used for the first time by Soviet scientists on space vehicles in 1964. The Zond-2 interplanetary station launched to Mars was provided with six plasma motors with electrical reaction propul-

sion for attitude control. The Voskhod 1 spaceship with its crew of three had, in addition to conventional engines, ion motors which were successfully tested. When the time comes for flights to other planetary systems of the Milky Way, rocket motors based on entirely new principles will have to be developed. Modern rockets are driven by the reaction force of gas jets produced by burning a chemical fuel. We have mentioned projects for nuclear rockets in which energy is generated by uranium fission or the synthesis of helium out of heavy hydrogen. Yet nuclear physics knows a much greater source of energy; the annihilation of particles.

Every elementary particle is known to have a corresponding antiparticle. The electron's antiparticle is the positively charged positron, which possesses similar properties. An antiproton differs from a proton only by its negative charge. The collision of a proton and antiproton results in their annihilation with the emission of an energetic "packet" of photons. The process is 100 per cent efficient, and it is hoped that the principle will one day be incorporated in the design of a photon rocket. Its design could be envisaged along the following lines. A stream of protons converges with a stream of antiprotons. The reaction of annihilation produces a flux of photons which impinge on a spherical reflector in the tail end of the rocket. A flux of photons—light in other words—exerts pressure, as was proved experimentally by the Russian physicist P. N. Lebedev several decades ago. The reflection of the photons by the mirror creates a thrust which accelerates the rocket.

Photon rockets will probably be the ultimate in uniflow propulsion systems. The exhaust velocity is the speed of light, and the flight velocity attainable in practice is restricted only by considerations of the theory of relativity. Obviously, today we can only surmise as to how the idea of photon propulsion will eventually be realized in practice.

According to one project, photon radiation is to consist of ultraviolet rays produced in incandescent metal vapour (or rather, plasma) at temperatures of 150,000 degrees C. An extremely low specific fuel consumption (of the order of 30 milligrams per second per ton of thrust) would enable a photon rocket with a year's supply of fuel and accelerating at 10 m/sec^2 to attain velocities comparable with the speed of light. Such spaceships would be capable of intergalactic travel.

To conclude this chapter, it would be of interest to consider some of the effects of the laws of relativity theory which would come into play in travels to distant stars. Suppose a spaceship takes off from a "parking orbit" around the earth in the direction of a star lying 1,000 light years away, and let it be travelling with a uniform acceleration of 10 m/sec^2 . The crew steering by the star will be able to observe the increase in speed by the Doppler shift in the star's spectrum towards the ultraviolet. In 1.4 years the shift in the spectral lines would tell them that their vehicle had attained 90 per cent the speed of light. After 5.6 years in flight they would observe that the wavelength of a certain beam of light radiating from the star had decreased from 5,900 to

11 angstroms, indicating that they were travelling at 99.9 per cent of the speed of light. Travelling the next 5.5 years without acceleration, i.e., 11 years in all, the vehicle would arrive in the neighbourhood of the star 1,000 light years from the earth. But although according to the clock in the rocket they had been travelling 11 years, clocks on earth and at the star would show that more than 1,000 years had passed. On the return trip, too, only 11 years would pass in the spaceship as compared with 1,000 years on earth. This is the famous time paradox of the theory of relativity.

✱

✱

10. THE PATH TO THE MOON

✱

✱

✱

✱

✱

✱

✱

Problems of rocket design and propulsion systems are not the only ones involved in preparing for lunar missions. For a rocket to reach the moon its trajectory must be computed with great accuracy and the flight carried out with equal accuracy.

Astronautically speaking, the trajectory is divided into two qualitatively distinct periods. The first is the boost period, in which the motors accelerate the rocket to the required velocity. When the motors are switched off the coasting period begins, in which the only forces acting on the rocket are the gravitational attractions of the earth, moon and sun. The boost period lasts only a few minutes, in which the rocket travels several hundred or even thousands of kilometres from the launching pad.

The rest of the journey of almost 400,000 kilometres is carried out in coasting flight. The maximum duration of the coasting period in a flight to the moon is 96 hours 18 minutes, or just over four days, for a rocket travelling in an elliptical orbit with the minimum velocity possible for the flight. Higher speeds cut the time substantially. At the escape velocity of 11.2 km/sec a flight to the moon lasts two days. and an additional 0.5 km/sec halves this time. Lunik 2, the world's first rocket to reach the moon, on September 14, 1959, travelled slightly faster than the escape velocity and crash-landed on the moon after a day and a half.

Although the boost period constitutes only a fraction of the coasting period in both duration and distance, it is far more important and the success of a mission will depend almost wholly on it. Correct calculation of the boost period and navigation in strict accordance with the computed variables is essential if the rocket is to reach its target.

The theoretical foundations of the mechanics of bodies with variable mass were developed by the Russian scientist Ivan Meshchersky, who gave the equation describing the motion of a rocket in space which is used to calculate the boost stage. The task consists essentially in computing the forces acting on the rocket at any moment of time: the thrust of its motors, the drag of the atmosphere and the weight of the rocket (that is, the gravitational pull of the earth). They act in different directions: the thrust pushes the rocket forward, the atmospheric drag directly opposes its motion, and gravity pulls it towards

the centre of the earth. These forces are not constant and they change during the rocket's flight. Thus, the drag depends on the velocity of the rocket and the density of the atmosphere. The gravitational pull (weight) changes because of the burning of the fuel and the increase in distance from the earth, and the thrust, too, may change in flight. The directions in which the forces act also change. In vertical flight they all act parallel to the longitudinal axis of the rocket, in inclined flight the thrust and drag act longitudinally and gravity acts at an angle to them; in curvilinear flight centrifugal forces also come into play. The rocket receives acceleration only if the thrust is greater than the resultant opposing forces.

For a rocket to reach the moon it must be lifted to a precise point of space over the surface of the earth and have a velocity of specified magnitude and direction. The free flight of the rocket in space (the coasting path) is calculated according to the laws of celestial mechanics like the motion of any other heavenly body. Computation of a trajectory to the moon is an extremely complicated and onerous job, and the need to be very careful in choosing the exact moment of launching necessitates the computation of many trajectory variants before the best can be selected.

The earth moves in its orbit around the sun with a velocity of approximately 30 km/sec. The moon, in turn, travels around the earth with a velocity of 1 km/sec in a complex orbit. The complete formula for the orbit, developed by Leonhard Euler, contains more than 700 terms.

For a rocket to hit the moon it must approach a point on the moon's orbit at the same time as the moon, which is not so simple, even though this "point" has a diameter of 3,473 kilometres.

In the simplest calculations the gravitational attraction of the moon can be neglected and the rocket must be launched towards a point ahead of the point occupied by the moon at launching time. In real conditions, of course, the moon exerts a changing gravitational attraction of its own, and matters are more complicated. In order to chart a rocket's trajectory its positions must be computed for time intervals of less than a second (remembering that a space vehicle will fly several kilometres in one second, and introducing corresponding changes in the gravitational attraction of the earth and moon).

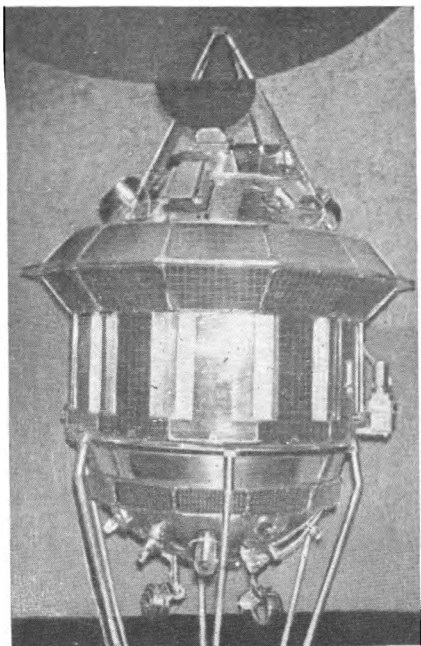
The Soviet scientist V. A. Yegorov has computed and described several types of trajectory for reaching the moon. They may be ellipses with the apogee on the moon's orbit or beyond it, parabolas or hyperbolas of different kinds with their focal points at the centre of the earth, and even a straight radical trajectory is theoretically possible.

Furthermore, as mentioned before, a rocket may hit the moon on either the ascending or descending portion of an elliptical orbit with an apogee beyond the lunar orbit. In the latter case the landing would be effected "on the way back".

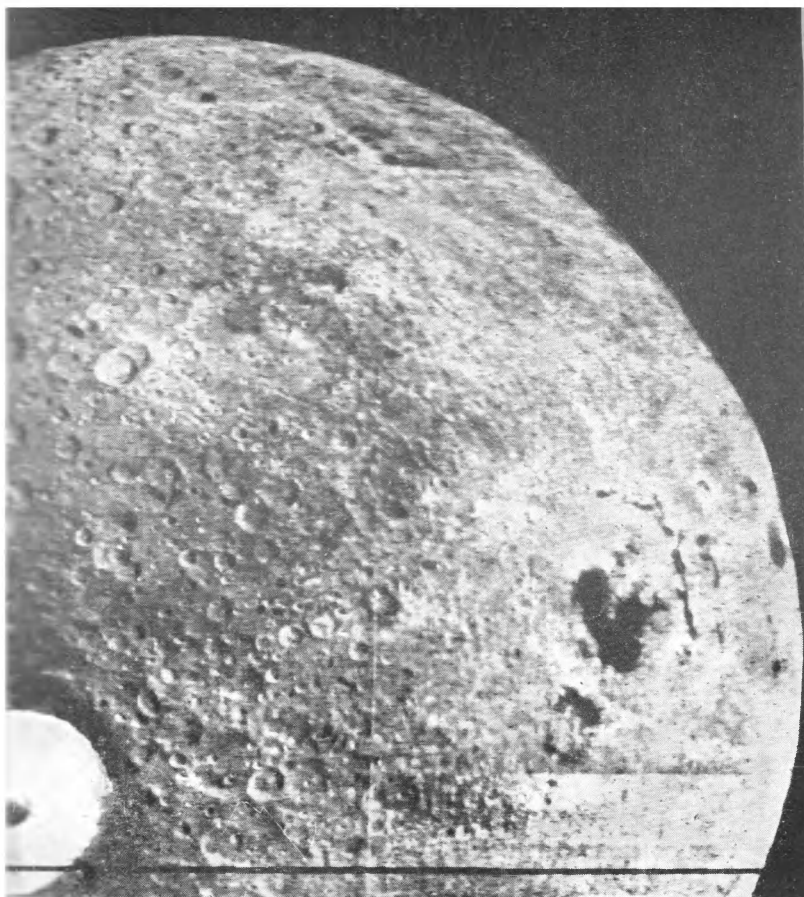
The type of trajectory is determined by the speed of flight. The least speed is required for a "grazing" elliptical path which just touches the moon's orbit.



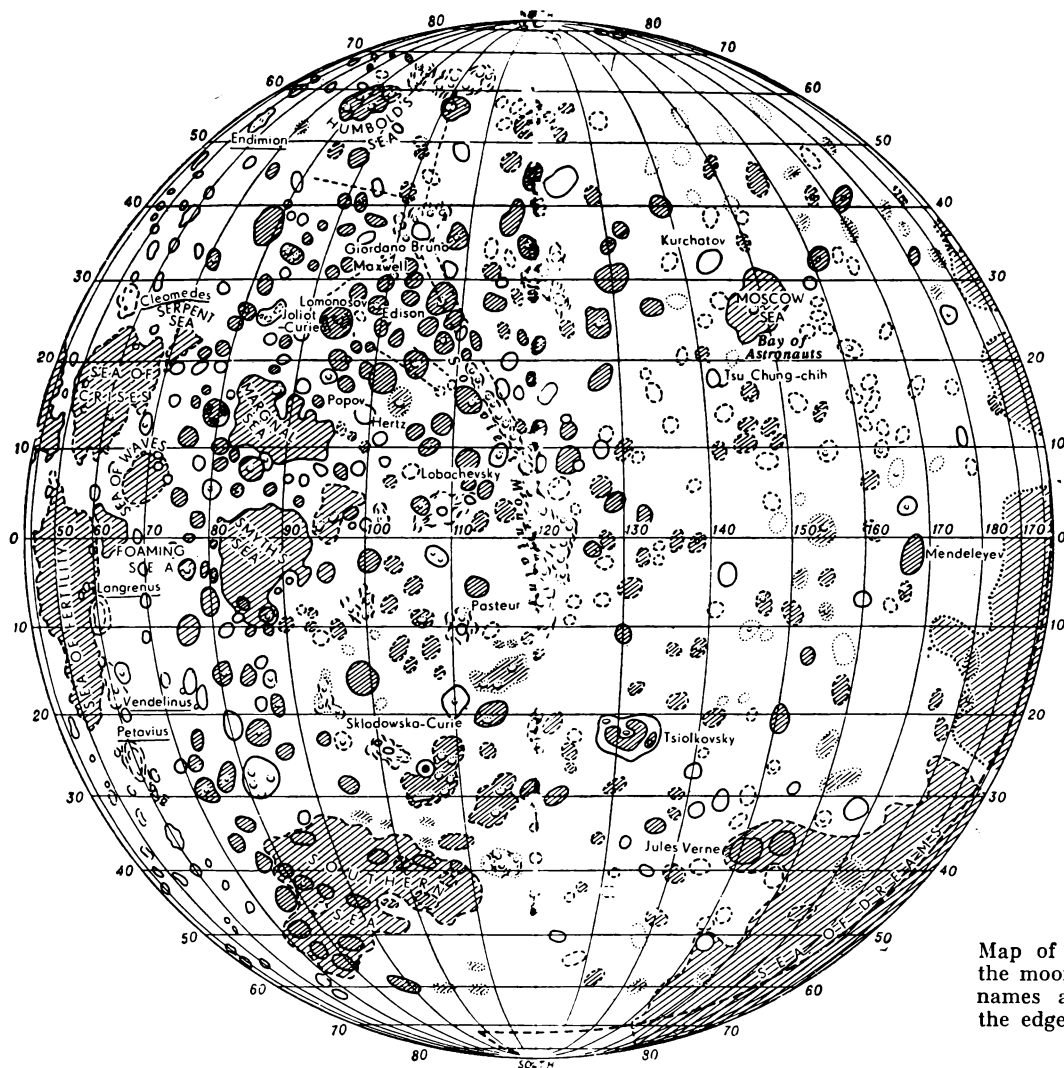
The neighbourhood of the craters Archimedes, Aristillus and Autolycus where Lunik 2 crashed into the moon



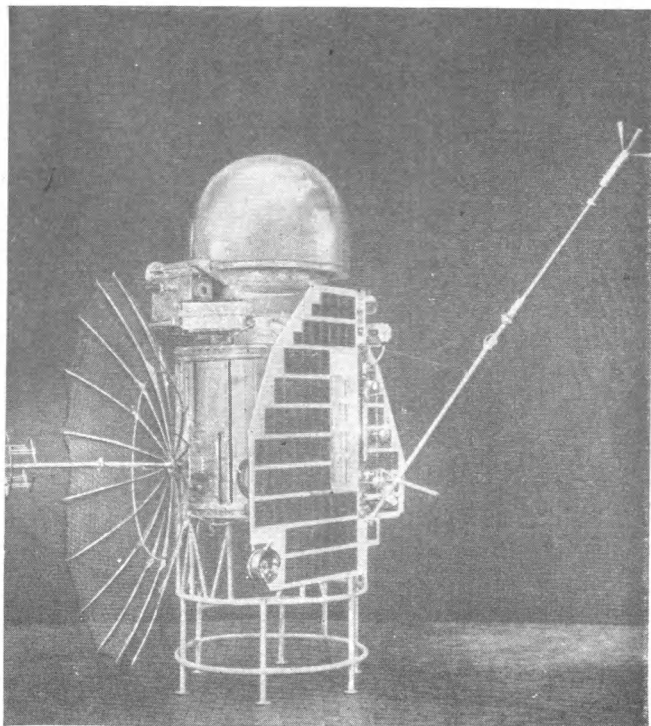
Lunik 3, which photographed the reverse side of the moon in October 1959



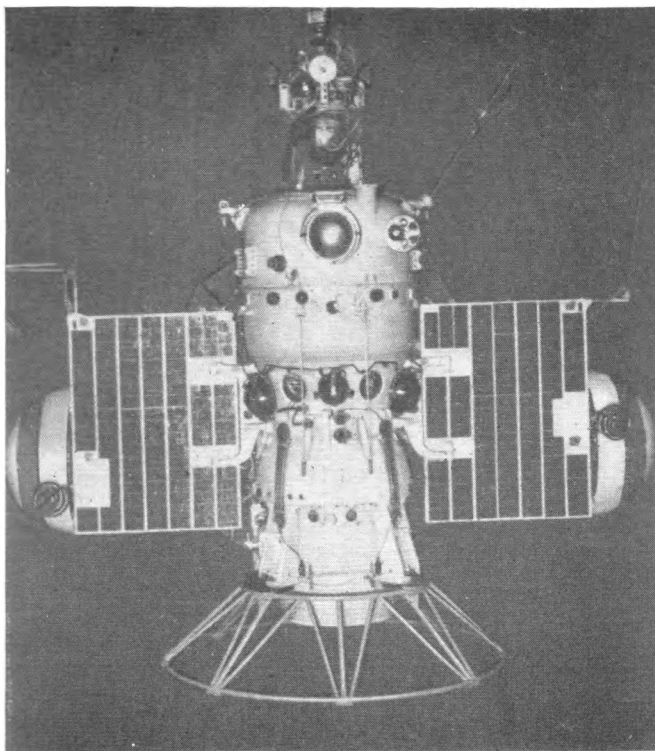
One of the photos of the back side of the moon made from the Soviet automatic interplanetary station "Zond-3" on July 20, 1965.



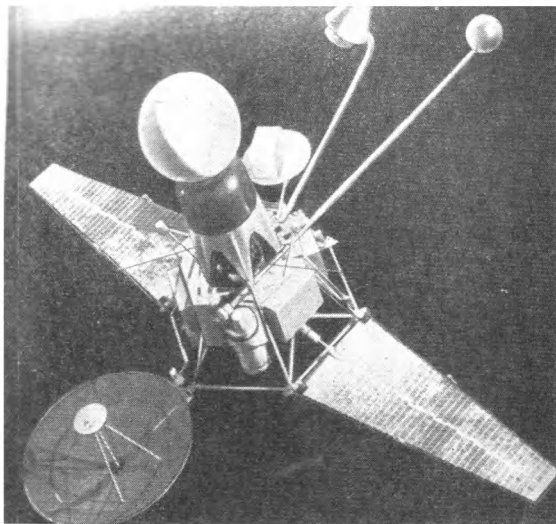
Map of the reverse side of the moon. The craters whose names are underlined lie on the edge of the visible side



The Soviet interplanetary probe Venus 1 which in February 1961 marked the beginning of interplanetary flight

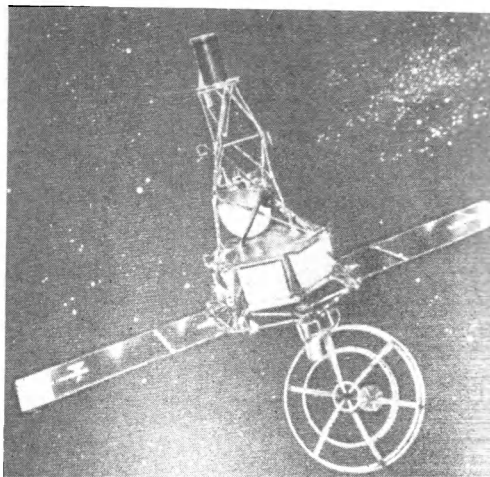


The Soviet interplanetary probe Mars 1



The American probe Mariner 2 which for the first time relayed to earth data about the temperature at the surface of the planet Venus

The Ranger spacecraft from which American scientists obtained several series of close-up photographs of the lunar surface



Another important consideration is the timing of a rocket launching. In principle, a moon-bound rocket can be launched at any time of day, that is, irrespective of the moon's position in its orbit around the sun. However, there are days when conditions are better or worse and the same amount of propellant can be used to launch a heavier or lighter rocket. The best time for launching a rocket from within the Soviet Union (if we wish to track it as it approaches its target) is when the moon is near its lower transit (when it is at its lowest position below the horizon; the highest position of a celestial body above the horizon is called its upper transit, or culmination). This means that the launching must take place about 12 hours after (or before) culmination time and the flight must last either 12 hours, or 36 hours, or two and a half days, etc. For Lunik 1, the duration of flight chosen was 36 hours. Accordingly, its velocity at the end of the boost period was somewhat more than the escape velocity. From the point of view of power expenditure the most advantageous time for launching a moon rocket from the Soviet Union is near the point of its orbit with minimum declination, which is about -18° . In this case the inclination of the rocket to the earth's surface in the boost period is the smallest and velocity losses due to gravity are reduced to a minimum, thus making possible a correspondingly greater payload.

Many other considerations must be taken into account in planning a lunar launching. Thus, a heavy vehicle taking off from the earth in an easterly direction receives additional kinetic

energy imparted by the rotation of the earth on its axis. At the equator this additional velocity is 465 m/sec (1525 ft/sec), in the middle latitudes it is about 250 m/sec (820 ft/sec).

And last but not least, there is the problem of landing on the moon. Two main variants are considered: a direct landing from an elliptical or parabolic trajectory from the earth, and a landing from a "parking" orbit around the moon. A rocket approaching the moon in a parabolic trajectory will be closing in with a speed of 3 km/sec (1.86 mi/sec) or more. As the moon has no atmosphere, landing can be effected only by using the rocket motors as brakes. Landing from a "parking" orbit may prove simpler, but there will be the added difficulty of placing the rocket in the orbit. If the vehicle flies more than 3,200 kilometres (2,000 miles) wide of the moon it will not be pulled into orbit and will either turn back to earth or sweep into an orbit around the sun. However, by judicious manipulation of the motors the astronauts will be able to place their vessel into a suitable orbit which, moreover, will not be affected by an atmosphere no matter how close to the surface it is. The astronauts will then leave their spaceship and spiral down to the moon in vehicles suitably designed to land safely, explore the surface and return to the mother ship again.

Communication between the lunar crew and the earth will be conducted by radio, with the use of radio telescopes. Computer centres will keep track of the spaceship and issue the necessary commands for adjusting its trajectory if necessary. The advantage of radio telescopes for

tracking lies in their high sensitivity and resolving power, which enables them to pick up weak signals over great distances. Furthermore, radio telescopes are capable of operating within a beam sufficiently narrow to establish the rocket's location with considerable accuracy.

✱

✱

11. MOON

✱

PROJECTS

✱

✱

✱

✱

✱

... ✱

K.E. Tsiolkovsky was one of the first men to place science-fiction on the sound basis of scientific theory and technological progress, and he made scientists and engineers the principal characters in his science-fiction story *Outside the Earth*.

What dreamers they were! Time and again they would put forward fantastically bold projects for travel through stellar space, but their own vast knowledge mercilessly shattered their dreams.

Now, however, science and engineering are advancing so rapidly in so many fields—nuclear power, space research, biology, cybernetics—that the science-fiction writers find it difficult to keep well ahead of reality. Things that only yesterday seemed remote and unattainable are today coming true. Tsiolkovsky had the gift of seeing

the future in its true perspective. He was a dreamer who was convinced of the feasibility and ultimate implementation of his dreams. Here is his plan of space conquest, which he drew up and believed in to the end of his days:

Men always proceed from the known to the unknown: from the sewing needle to the sewing machine, from the knife to the meat-grinder, from the flail to the threshing machine, from the stage coach to the automobile, from the canoe to the ship. Thus we envisage the advance from the aeroplane to the reaction-propulsion vehicle for the conquest of the solar system. We have already pointed out that, as a rocket will inevitably have to begin its flight in the air, it must be provided with some of the features of the aeroplane. But we have also shown that wheels, propellers, engine, burdensome wings and permeable compartments will be unsuitable. They all combine to prevent the aeroplane from attaining speeds higher than 200 m/sec or 720 km/hr. But gradually the aeroplane may become suitable for space travel. Even today, an aeroplane flying at an altitude of 12 kilometres leaves below 70-80 per cent of the atmosphere and approaches the region of pure ether surrounding the earth. Let us help it achieve more. Here, roughly, are the stages of transformation and advance in aeronautics needed to achieve higher goals.

1. A rocket plane with wings and conventional controls is built, but its petrol engine is replaced by a rocket motor into which a small pump supplies an explosive propellant. There is no propeller. There is a stock of propellant and a compartment for the pilot with a transparent dome to protect him from the wind as the velocity of this apparatus is greater than that of an aeroplane. The reaction force of the burning propellant will push the system on runners travelling on greased rails (as the velocity is not great wheels can be retained). Then it will take off, attain its maximum velocity, use up the whole of its reserve of propellant and, reduced in weight, will glide like an ordinary aeroplane or motorless sailplane to land safely on the ground. The amount of propellant and the thrust may be increased gradually so as to increase the maximum velocity, range and, most important,

altitude of flight. As the pilot's compartment is not airtight the aeroplane will be unable to climb higher than 5 kilometres. The purpose of these tests is to train the pilot in controlling the aeroplane (at high velocities), the rocket motor and the gliding flight.

2. In subsequent vehicles the wings must be gradually reduced in size and the engine power and velocity increased. It will be necessary to obtain a preliminary velocity by previously described means before rocket propulsion begins.

3. The hulls of subsequent vessels must be made airtight, filled with oxygen and provided with installations for absorbing carbon dioxide, ammonia and other products of human excretion. The purpose is to climb to an altitude where the atmosphere is rarefied. The altitude may greatly exceed 12 kilometres. In view of the high velocity the landing is more safely effected on water. The impermeability of the rocket hull will not allow it to sink.

4. When the rocket attains very high altitudes it must be provided with rudders of the type described by me before which operate well in a vacuum and in highly rarefied air. A wingless craft, with a double- or triple-walled hull, filled with oxygen, hermetically sealed and capable of gliding well, is used. For ascent it requires a high initial speed, and the take-off systems must therefore be improved. The added velocity enables it to ascend higher and higher. Centrifugal force will by then come into play and reduce the work of propulsion.

5. The velocity reaches 8 km/sec, the centrifugal force completely counteracts gravity and the rocket leaves the atmosphere for the first time. After flying there as long as the oxygen and food last, it spirals down to earth, braking in the air and gliding without switching on the motors.

6. After that a plain hull can be used instead of a double one. Flights in the atmosphere continue. Rocket craft fly farther and farther from the earth's atmosphere and remain in the ether for longer and longer periods. However, they must return as their stocks of food and oxygen are limited.

7. Attempts are made to get rid of carbon dioxide and other human excretions with the aid of selected small plants, which also yield nutrient substances. Much

work is carried out on this problem and success is slowly but surely achieved.

8. Ether suits are developed for men to leave the rocket safely.

9. Special compartments for plants are devised in order to produce oxygen and food and purify the air in the rocket. They are delivered by rockets into the ether in parts and then joined together. Man becomes independent of the earth as he can produce all the things needed to support life.

10. Big settlements are established around the earth.

11. Solar energy is used not only for producing food and living conveniences but also for travel throughout the solar system.

12. Colonies are established in the asteroid belt and in other parts of the solar system where small celestial bodies are found.

13. Industry develops.

14. Individual (personal) and public (socialist) perfection is achieved.

15. The population of the solar system increases to 100,000 million times the present population of the earth. The limit is achieved beyond which migration to the whole of the Milky Way is inevitable.

16. Cooling of the sun begins. The remaining population of the solar system departs to other suns settled by their brothers who had left earlier.

One should not imagine that the projects of the school teacher from Kaluga are mere dreams and fancy. K. E. Tsiolkovsky was a realistically thinking man of creative quest and practical action. For more than 35 years he developed the fundamentals of rocket dynamics and astronautics. A comparison of his researches with later works of scientists in other countries shows that the theoretical foundations of interplanetary flight were in fact laid in Russia. The test of time serves to demonstrate more and more vividly the scope and loftiness of Tsiolkovsky's ideas.

At present many projects for flights to the moon have been drawn up. The technical problems they pose are indeed feasible. Thus, at the eighth international astronautical congress in Barcelona, a project put forward by the American Goodyear Aircraft Company was discussed. It considers the establishment of small manned satellites launched by intercontinental ballistic missiles (ICBM). The basic structural unit is the Meteor Junior rocket, which in the initial stages is envisaged as a structural element for an interplanetary station, subsequently to be used for flight to the moon and back to the orbital station and to earth.

Meteor Junior is a three-stage rocket weighing from 90 to 450 tons, depending on the mission on which it is to be employed. The third stage has accommodation for a two-man crew, the first and second stages representing modifications of conventional ICBMs. As progress is made in the design and utilization of Meteor Junior, the weight of its stages is to be increased, with the crew of the third stage being increased to four and the payload to one ton. The first and second stages are jettisoned as they burn out their fuel and glide back to earth for further use with new motors. The aggregate thrust of the 27 motors needed to launch the rocket into an orbit 800 kilometres above the earth is 1,134 tons. The first stage has 17 motors of 59.2 tons thrust each, the second has 6 motors of 20 tons thrust each, and the third has four motors of 2.25 tons thrust each.

The project envisages the use of liquid fluorine as oxidizer which, the designers hope, will

enable them to obtain a propellant specific impulse of up to 275 kg-sec per kg at sea level. Several motors on each stage are mounted on swivel supports to provide for stabilization and attitude control. At second-stage burnout the third stage must have a velocity of 24,000 km/hr. It has been stressed that the cost of this project is substantially less than that of earlier projects. Each rocket stage is expected to cost several million dollars, but new motors for a stage being re-used will cost only some 10,000 dollars.

The total cost of a lunar station is estimated at 30 million dollars with various supplementary expenditures, but without taking into account the cost of rocket development which may run up to several times the sum. The authors of the project are quick to point out such difficulties as aerodynamic problems, the effects of ionization and molecule dissociation at high altitudes, stability and controllability outside the atmosphere, synchronization of motor operation and others. Nevertheless, they hope that an interplanetary station can be built along these lines within a few years.

In the later stages of the project it is intended to build in quarters for crew members also in the first two rocket stages. The crew is to be trained, in installations simulating real flight conditions, while the third stage is being constructed. When the third stage is completed the crew will carry out several test flights in conditions analogous to orbital flight and re-entry. It is suggested that the slightly modified third-stage rocket will be used for flight to the moon

from an orbital station or straight from earth. For this a fourth stage rocket is to be added. the overall weight of the complex increasing to 155 tons. This will make it possible to ensure a soft landing on the moon and return to earth.

When the third-stage rocket is to be used as a structural element of an interplanetary station or for ferrying cargoes to the station, it will be additionally provided with a homing system for injection into orbit and closing in with the interplanetary station.

North American and Lockheed corporations report a lunar project called Harvest Moon with a two-stage rocket. The power plant of the first stage is to be the motor of the discarded Navajo intercontinental missile. Lockheed's X-17 rocket is to be used for the second stage. According to the designers, such a two-stage rocket could take off for the moon within six months from the beginning of work.

Experts of the U.S. National Aeronautical and Space Administration (NASA) envisage three possible methods of sending expeditions to the moon. The first is a direct flight in a multi-stage rocket of sufficient size to reach the moon, land a manned space vehicle with all the necessary exploration gear and return to earth. The second provides for a rendezvous of two rockets in a terrestrial orbit for refuelling, with the refuelled rocket going on to the moon. The third also provides for a rendezvous, but in a lunar orbit. According to this project a spaceship is placed in orbit around the moon, and a small capsule, designated lunar excursion module (LEM), is

landed there and then returns to the mother ship for flight back to earth.

Each of these moon projects is subdivided into several stages, and the probability of success depends on the success of each element in the overall programme. The idea of establishing intermediate "parking orbits" around the earth, moon or both is an extremely useful one, and it is designed to reduce the initial weight of moon ships. Thus, it has been calculated that a manned spaceship with a crew of three and weighing four tons designed to circle the moon and return to earth requires a launching assembly with an initial weight of 176 tons, including 156 tons of fuel.

By way of comparison, the launching of the same vehicle into a terrestrial orbit can be carried out by a rocket weighing 40 tons with 29 tons of fuel. It has been calculated that the launching of a payload of 176 tons into a circular orbit at an altitude of 550 kilometres would require a carrier rocket with a first-stage thrust of 5,500 tons. These figures demonstrate the advisability of assembling big orbital spaceships outside the earth; then the component parts could be delivered into orbit by carrier rockets with a first-stage thrust of only around 3,500 tons. The orbiting station would serve as a fuelling station in outer space. Shuttle rockets could be used to deliver unfuelled vehicles and fuel to the orbiting station, where the interplanetary craft could be fuelled for further flight. The ferry rockets would of course be able to deliver all the gear and equipment needed for moon missions.

An extension of the "parking orbit" idea is one in which a carrier rocket places a space station in a satellite orbit around the moon some 80-160 kilometres from the surface. A capsule weighing 2-5 tons with a crew of two is landed on the moon. The men are provided with spacesuits enabling them to leave the rocket and explore the neighbourhood on foot. Air purification and other life supporting systems are carried in backpacks, which will not weigh much on the moon.

A variety of life supporting systems have been suggested. Thus, under the U.S. Mercury project, oxygen for breathing is to be stored in liquid form, water will be used for temperature control, lithium hydroxide for absorbing carbon dioxide, and activated carbon for deodorization. For safety's sake the first men on the moon would probably be best advised not to leave the shelter of their capsule. After carrying out their programme of work they would launch it from the moon and return to the spaceship. The capsule would then be discarded and the explorers would return to earth.

The advantage of the above programme is that the initial weight of the whole system can be brought down to 100 tons, enabling a carrier-rocket with a thrust of 3,400 tons, like the Saturn V, to be used for establishing the parking orbit around the earth.

Rendezvous in orbits can be used to assemble manned stations weighing several hundred tons from structural elements. They can be used as flying laboratories for prolonged studies of outer space, solar activity, the planets and stars

without being handicapped by atmospheric interference. They can also carry out regular meteorological observations, etc.

Landing on the moon from a lunar orbit has the great advantage of allowing the use of a small landing capsule. Guidance of a small vehicle is obviously a much simpler matter, and the problem of return to the base spaceship should be no more difficult than a rendezvous in a terrestrial orbit.

American research workers are tackling the rendezvous-in-space problem with a Gemini capsule designed for two men. First an Atlas rocket places an Agena B satellite station into a circular orbit at an altitude of 300 miles. When the orbital parameters are verified, a Titan II injects the Gemini capsule into a 150-mile orbit lying in the same plane. As the Gemini orbit is closer to earth, the capsule will be travelling faster than Agena. When the two vehicles occupy a preset mutual position, the astronauts switch on the Gemini rockets to gain an elliptical orbit close to Agena. If all goes well the men will be able to detect the rocket by radar or visually. Although the two craft travel at some 18,000 miles an hour they approach at the relatively low speed of 75 mph. Gradually the astronauts will reduce the speed, while keeping track of the Agena capsule by means of Doppler radar measurements. At a suitable moment they transfer the capsule to a circular orbit. In the final stage of the experiment the Gemini capsule separates from the rocket and returns to earth.

Here is another technically feasible project for a flight to the moon. Imagine a huge multi-

stage rocket more than 165 feet high and weighing 3,039.6 tons. The first stage weighs 2,268 tons and the diameter of its base is 48 feet. There are six stages in all, the final one being a capsule with accommodation for two astronauts. At blast-off the six motors of the first stage go into action. In 10 seconds the rocket lifts its bulk off the launching pad. First-stage burnout takes place a little more than two minutes later at an altitude of 35 miles. The empty shell of the first stage drifts to earth on parachutes and the second-stage motors start firing. In 177 seconds the rocket climbs to an altitude of 85 miles and has a velocity of almost 3 miles per second. The second stage separates and burns up in the atmosphere. The third stage sets the spaceship on its course to the moon. The trip lasts 60 hours. As the rocket approaches the moon the astronauts take over control to orientate it in space. Attitude control is effected with the help of small auxiliary rockets. The fourth-stage motors are switched on to provide the necessary retardation for a soft landing. The rocket throws out its landing gear—a system of socketed rods which unfold into a landing pad 40 feet in diameter. The capsule touches the moon's surface not far from a pilotless rocket dispatched in advance to serve as a lifeboat in case of emergency.

After carrying out their programme on the moon the astronauts board their ship and switch on the motors of the fifth-stage rocket. Twenty seconds later the fuel burns out and the stage is jettisoned to the moon. The astronauts navigate their spacecraft into the trajectory which

takes them in free flight to the earth. Re-entry into the earth's atmosphere is effected at a very small angle to ensure braking in the atmosphere without burning up. Some six or seven miles from the ground a big parachute opens and the moon travellers alight on mother earth.

Plans announced by NASA provide for three modifications of the Apollo spaceship, designated A, B and C, and designed respectively for a circumterrestrial orbit, a circumlunar flight and landing on the moon and returning to earth. Apollo A will have a command module, which will house the crew and scientific hardware and a service module, which houses the rocket motors. Apollo B will be similarly designed, and Apollo C will additionally carry a special vehicle, called the lunar excursion module (LEM) with all the systems needed for landing on, exploring, and taking off from, the moon. According to data published in the magazine *Missiles and Rockets*, the Appollo C command module is 15 feet long and 13 feet in diameter at the base. It will weigh 3.6-4.5 tons and will be provided with jet engines for steering and attitude control, operating on hydrazine and nitrogen tetroxide. The module's shape and an offset centre of gravity give the spacecraft some lift in the atmosphere which will enable the astronauts to manoeuvre it by using roll jets when it enters the atmosphere. The lunar excursion module is especially designed for lunar landing and take-off. The descent stage and landing gear will be left on the moon when the LEM blast off for the return trip to earth. The Appollo control systems are being developed by the instrumen-

tation laboratory of the Massachusetts Institute of Technology. First the Apollo A instrumentation will be developed, be subsequently modified for the other two types. Apollo C will be equipped with an inertial guidance system with provision for radar and optical control and adjustment. In the middle period of the journey to the moon and back radio command and astro-inertial guidance equipment will be employed. The systems are both automatically and manually controlled.

Explorers of the moon will have to be suitably attired, and several types of protective suits have been designed. One such suit is a cylindrical aluminium capsule with a transparent bubble dome and flexible legs, and is equipped with radio, oxygen supply, air conditioning, power sources, lighting, food storage pockets and other devices, including a tripod for sitting down.

The suit in which the first Soviet cosmonaut will alight on the moon will be an advanced modification of the design tested by Alexei Leonov when he left the spaceship Voskhod 2 for man's first jaunt in outer space. His suit differed in many respects from those used by the first cosmonauts. New features included an oxygen backpack, heat reflecting surface, electrical heating of the helmet window and a radiotelephone system for communication with the ship. As Leonov reported on his return to earth, the suit proved its worth for work in outer space.

The research programmes of the first men on the moon will include many observations, such as measuring the moon's mass and magnetic field, the structure of indigenous rock and sedi-

ments from outer space, seismic activity, if any, the formation of gases beneath the surface and measurement of the density of the atmosphere. Not all of these investigations require a landing on the moon; gravity and magnetic field measurements can be carried out from an orbiting vehicle and even by unmanned probes.

As mentioned before, there are many projects for exploring the moon and it is hard to say which one will be implemented first. In any case, however, progress to date leaves no doubt as to the feasibility of trips to the moon in the not too distant future.

We have already said that on January 2, 1959, the world's first space rocket was launched towards the moon. It attained the escape velocity then exceeded it, skimmed past the moon at a distance of 3,700 miles and became the first artificial planet of the solar system. The probe was launched by Soviet scientists to carry out a series of experiments and measurements in outer space with the purpose of studying the neighbourhood of the earth and moon. Automatic systems switched off the last-stage motors when the required velocity was achieved and ensured flight and attitude control.

Lunik 1 carried its instrumentation payload in the last-stage rocket and a space capsule. Their total weight was 1,472 kilograms (3,245 pounds). On the way to the moon the rocket ejected a cloud of sodium which expanded to 60 miles in diameter and was photographed on earth as an artificial comet of sixth stellar magnitude. The last-stage rocket carried the spherical 361-kilogram (796-pound space probe in its nose). The

bulk of the research programme was carried out by the instrument pack of the probe. After third-stage burnout, the nose cone opened, the probe came out, extended its antennae and switched on its transmitters. The programme included studies of the gaseous component of interplanetary matter, the sun's corpuscular radiation, measurement of the earth's magnetic field and detection of a lunar magnetic field, registration of meteoric impacts and cosmic radiation. Other instruments continuously measured the parameter of the probe's trajectory and maintained the established temperature and pressure inside the capsule. The last-stage rocket also carried a cosmic ray intensity recorder. The first man-made planet is now revolving around the sun once every 450 days.

In September 1959, Lunik 2 was launched to continue the Soviet space programme, one aspect of which is the study of the region between the earth and the moon with an eye on future manned flight and unmanned automatic orbital stations. Lunik 2 was the first man-made object to be delivered to another celestial body. It was essentially like Lunik 1, though somewhat heavier, the last stage weighing 1,511 kilograms (3,331 pounds) (without the propellant). The space probe including the instruments weighed 390 kilograms (860 pounds). A sophisticated automatic tracking system on earth continuously processed the trajectory data with the help of high-speed computers. The transmitters on board the rocket relayed to earth important scientific information. The flight programme was basically the same as that of Lunik 1, with the exception

that Lunik 2 was to crash land on the moon. This was carried out, and 36 hours after blast-off it landed a pennant bearing the hammer and sickle on the surface of the earth's natural satellite.

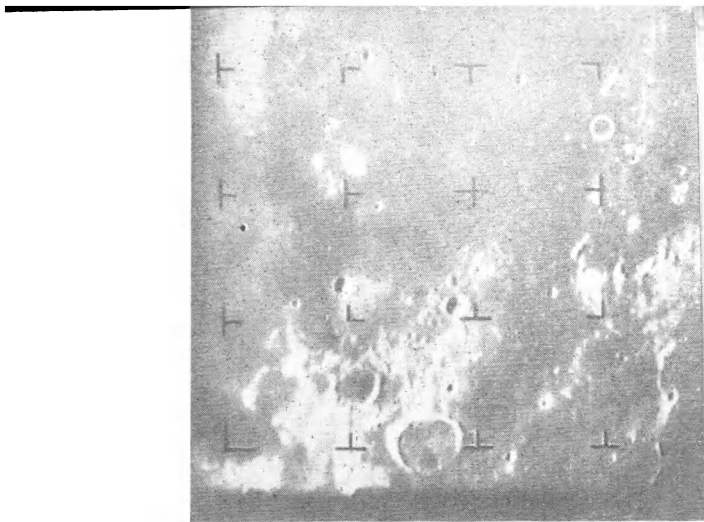
On October 4, 1959, the U.S.S.R. launched its third interplanetary probe. A 1.5-ton rocket carried an automatic interplanetary station weighing 278 kilograms (613 pounds) towards the moon. It photographed the far side of the earth's natural satellite and transmitted the pictures back to earth. The photographic camera was equipped with two lenses of different focal length, one for taking pictures of the whole lunar disk, the other for close-up pictures of various sections of the disk. For 40 minutes the camera took many pictures of the far side. This was effected in the following way. When the interplanetary station was passing round the moon a command was transmitted by radio from the earth which turned the station so as to aim the camera lenses at the moon. When the pictures were taken they were automatically developed, fixed and dried. After several days, when the automatic station approached the earth again, the images of the negatives were transmitted by television to receiving stations in the Soviet Union. These photographs marked a new stage in the exploration of the moon. Many of the features discovered on the far side of the moon have been named after prominent scientists and science writers: Tsiolkovsky, Lomonosov, Joliot-Curie, Giordano Bruno, Maxwell, Edison, Popov, Hertz, Lobachevsky, Pasteur, Mendeleyev and others. One

of the newly discovered seas has been named the Moscow Sea or, following selenographic tradition, Mare Muscoviae. At its southern edge lies the Bay of Astronauts. The biggest sea on the far side has been named the Sea of Dreams, and the biggest mountain system is called the Soviet Mountain range.

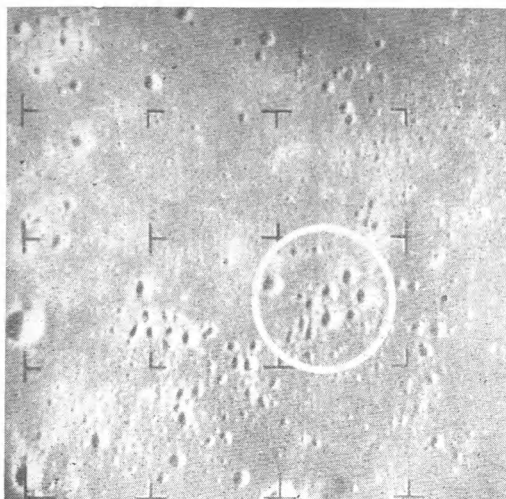
On April 2, 1963, the fourth Soviet moon probe was launched. This experiment differed markedly from the previous launchings in one important detail: the last stage of the carrier rocket was first placed in a circumterrestrial parking orbit from which it was launched at a predetermined moment. The automatic station reached the moon in three and a half days, and once again much important information was obtained concerning the neighbourhood of the moon and earth.

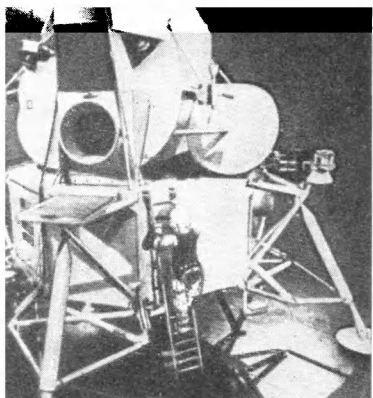
In 1964, after several failures, the U.S. Ranger project finally went off to a good start. On 31 July, Ranger 7 transmitted to earth several thousand close-up pictures of moon taken up till the moment when it crashed into the surface. A study of these photographs, and those of Ranger 8 and 9 which followed several months later provided important new data concerning the nature of the moon's surface which will be of special value for future lunar missions.

When Voskhod 1, the first three-man spaceship, returned after its day in orbit, Victor Komarov, the commander, commented that now he and crew members Konstantin Feoktistov and Boris Yegorov hoped to be signed up for a lunar mission. Asked to sum up in one sentence the significance of the Voskhod 2 flight and Alexei Leo-



The top photograph was taken in 1964 by Ranger 7 from a distance of 480 miles. The bottom photograph is of the same area from a height of 34 miles

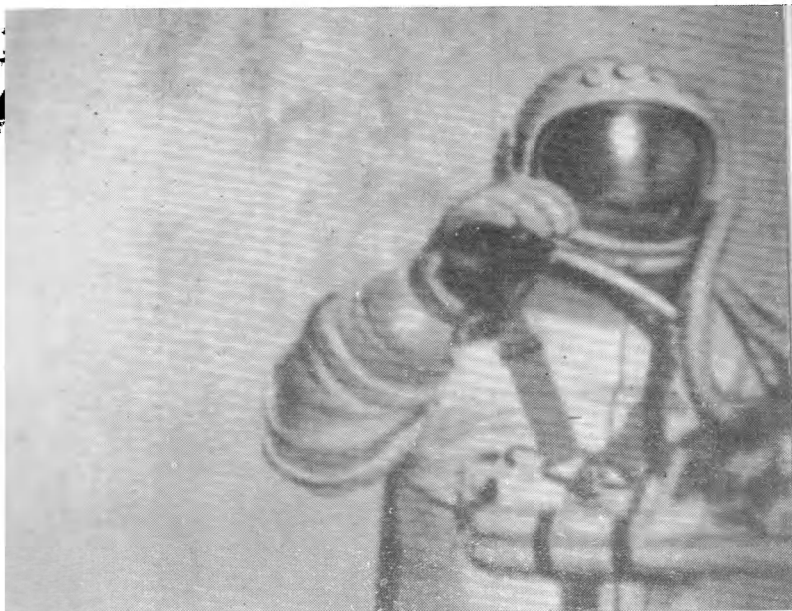




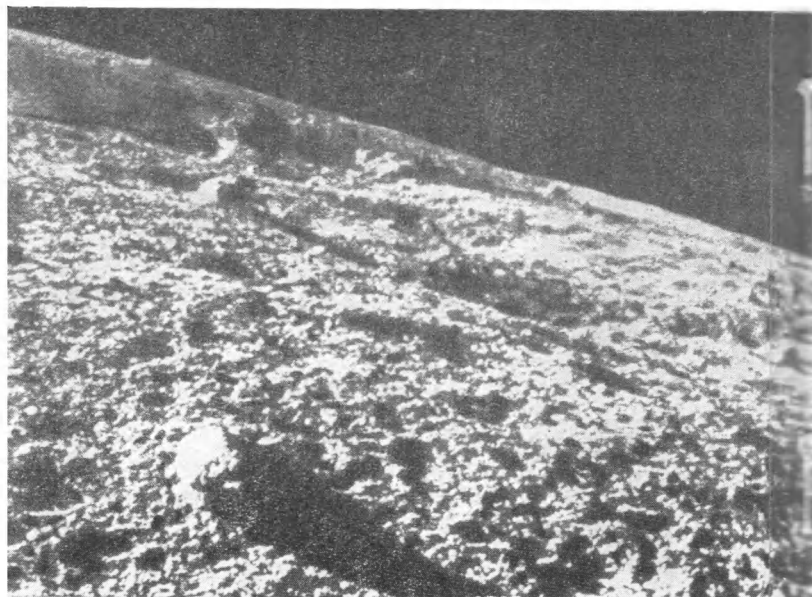
A mock-up of the Lunar Ex-
cursion Module (LEM) de-
signed for landing two men
on the moon under the
American Apollo programme

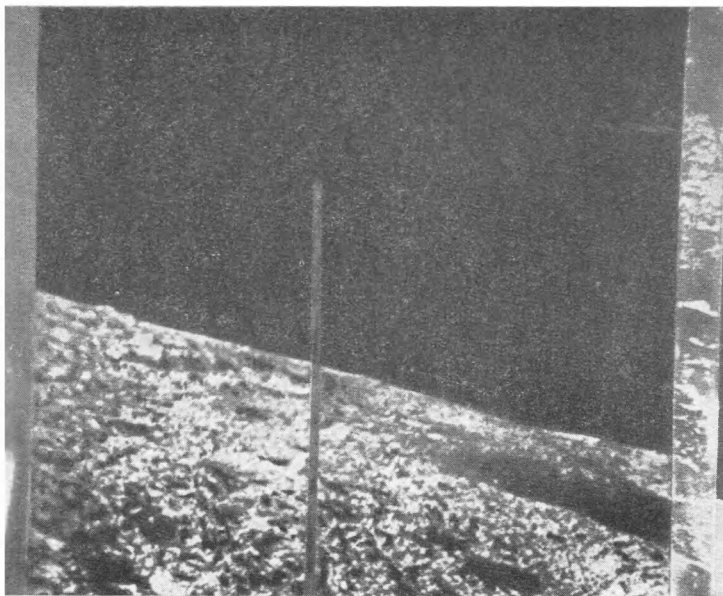
American astronauts will be
dressed in spacesuits like
this when they land on the
moon



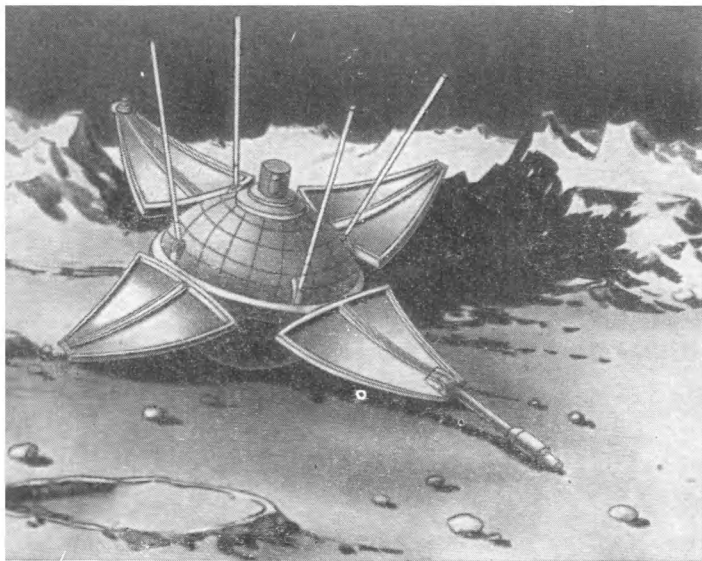


Alexei Leonov walks in outer space. His spacesuit offers reliable protection against the hazards of the environment and makes work possible. Spacesuits like this will be used when Soviet cosmonauts land on the moon

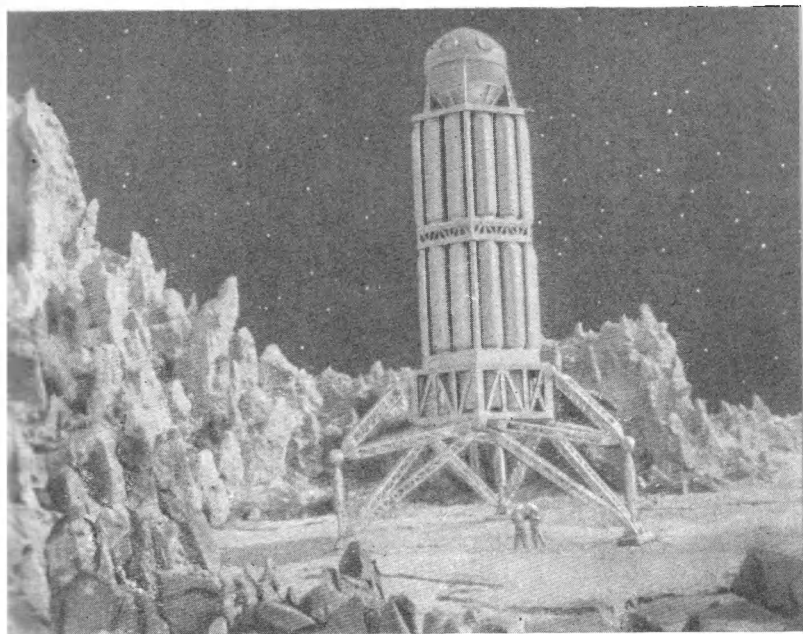




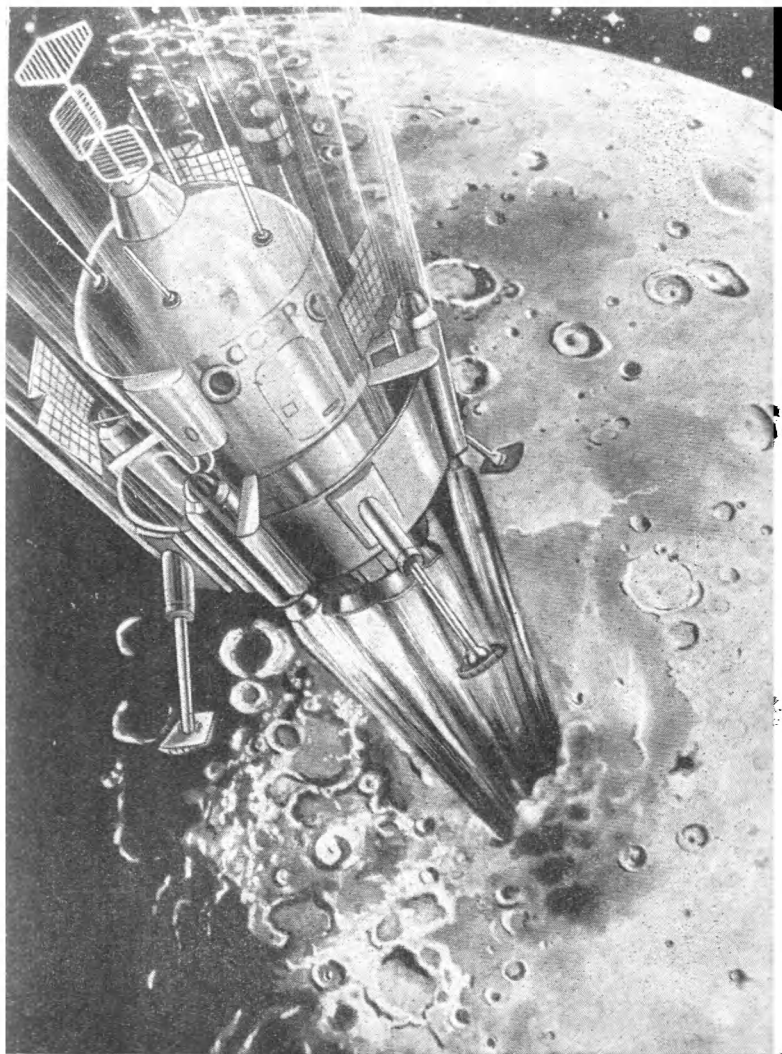
A portion of the moonscape panorama
transmitted by the Soviet automatic
station Luna 9 in February 1966



An artist's impression of Luna 9 on the surface of the moon



A spaceship on the moon as envisaged in a Soviet science film



A lunar ship lands in the Ocean of Storms. Drawing by cosmonaut Alexei Leonov

nov's exploit in leaving the craft, Feoktistov said, "Moon launchings have come much nearer".

Sure enough, only two months later, on 9 May 1965, Lunik 5 was launched from the Soviet Union to pioneer the development of a soft landing system of the kind that will be needed if we ever hope to visit the moon and planets of the solar system. In this launching attitude control, space orientation, trajectory correction and automatic and telecontrol systems were tested along with the lunar landing gear.

These are some of the initial results of the first lunar probes which have ushered in the era of direct exploration of cosmic bodies and planets and are paving the way for manned interplanetary flight. There can be no doubt that it will soon be accomplished. The human mind is capable of overcoming all the difficulties of such projects, and by the end of the twentieth century trips to the moon may become as common as tourist jaunts to other countries.

✱

✱

12. ROBOTS ON THE MOON

✱

✱

✱

✱

✱

✱

✱

The moon will have to be studied in as much detail as possible before the first men are sent there. Automatic instruments will study its gravitational and magnetic fields, the radioactivity of its surface and the heat convection below the surface, the chemical structure of lunar rock and the physical features of its terrain. The moon exploration programme can be divided into three main stages: crash-landing of instruments, soft landing of robots, and manned expeditions. The first stage of lunar exploration is currently being carried out by Soviet and American scientists.

As described earlier, photographic cameras and various instruments are used to relay information back to earth before they smash to smithereens on lunar rocks.

The next step will be to encase instruments in a shell to keep them intact when the shell breaks. According to one project, a seismometer is to be delivered in this way to the neighbourhood of the crater Alphonsus, from which it will telemeter to earth information about seismic activity on the moon. Other crash-landed instruments will, it is hoped, transmit information about the structure of the lunar soil and its suitability for soft landings.

When this and other data are duly collected and processed scientists will start planning a robot expedition. A robot with telescopic and television eyes and an electronic brain invested with a complex programme of research will relay to earth invaluable information. The main task is to land it on the moon in working condition. The first test of a soft landing system was carried out in the autumn of 1964 by the manned Soviet orbital spaceship Voskhod with its crew of three. According to the cosmonauts, the landing was so soft that they even missed the precise moment when the capsule touched the ground. Equally successful was the landing of Voskhod 2 in March 1965. Lunik 5, as mentioned before, carried out the first test of a soft landing system on the moon.

An important part of the moon exploration project is the development of a vehicle capable of negotiating the lunar relief. On earth we have many automatic devices for steering and control, like autopilots in aircraft, automatic helmsmen in ships and automatic train drivers. They can maintain the required speed, manoeuvre and in some cases of skirt obstacles. A "lunamobile"

will, of course, have to include many specific features. Some designers suggest a vehicle capable of boring through lunar dust. Some envisage a "jumping" machine propelled by small rockets. Some suggest walking machines on hinged steel limbs.

The moon is a rugged world and any vehicle negotiating its terrain will have to clamber up and down steep slopes, cross cracks and fissures, climb in and out of craters and possibly wade through deep dust. In other words, a "lunamobile" must be a truly cross-country vehicle. One engineer suggests a combination of walking "legs" with track-laying "feet". Such a vehicle would be able to ride over loose sand or dust, crawl up slopes and step over fissures. In another design the vehicle travels on three wheels. As pneumatic tyres are unsuitable for lunar conditions the wheels will have shock-absorbing spokes. The chassis will carry the robot equipment, and in future it can be used to carry a pressurized cabin with accommodation for one, two or three astronauts.

The first moon robots will carry out many important investigations. They will measure the temperature at the surface during the lunar day and night. They will explode special bombs to study the speed with which sound travels through lunar rock. Automatic drilling rigs will bore into the moon's crust to carry out a selenological programme which will include studies of physical conditions below the surface. An X-ray spectrometer will be used to determine the percentages of metals and other elements in lunar rock. X-ray diffractometers and gas chromato-

graphs will provide detailed information about gases and organic compounds on the moon. Meteorological instruments will measure the atmospheric pressure and composition of whatever traces of atmosphere they can detect. Investigations of the moon's magnetic field will be continued on the surface, and Geiger counters will report on the energy range of particles pouring in from outer space.

Moon robots will undoubtedly also be controlled from earth, and here an interesting problem arises. A radio signal takes 1.28 seconds to travel the distance from the earth to the moon. So if an emergency situation ever develops, it will take at least 3 seconds for the robot's SOS signal to reach the earth, be deciphered, and the necessary command to be issued and reach the robot again. Three seconds is not very long to be sure, but it is sufficient for a lunar vehicle travelling at 6 miles an hour to go another 20 feet, which could well take it over the brink of a precipice. That is why it is very important for the electronic driver to be capable of responding to such situations, without waiting for a command from the earth. A TV camera rotating on a high tripod would be able to scan the moon's surface, warning of possible dangers as well as relaying scenes of the moonscape back to earth. Eventually, of course, moon robots will be landed to study and prepare sites for manned expeditions.

✱

✱

13. THE FIRST MEN ON THE MOON

✱

✱

✱

✱

✱

✱

✱

Dead silence enveloped the motionless rocket. The two men seemed stunned, as if they had just woken up from a dead sleep or come to after fainting. Finally the Russian rose to his feet, stretched himself, and said: 'We're on the moon...'

Everything around them sparkled and shone in the rays of the Sun. High mountains loomed in the distance. They were standing on the fairly smooth floor of one of the so-called 'seas'. The Sun warmed them and they felt no cold from the soil. They looked about thoughtfully for several minutes. But they soon had to move about, as their suits grew too hot on the sunny side and too cold on the shady side... What a new world lay before them! What a wealth of astonishing discoveries!

K. E. Tsiolkovsky wrote this back in 1896¹. What will the first men on the moon do?

¹ *Outside the Earth*, printed in *The Call of the Cosmos*, a collection of science fiction by K. E. Tsiolkovsky, Foreign Languages Publishing House, Moscow, U.S.S.R.

Surely they will have undertaken their dangerous trip not just to hoist the flag of their nation, nor even to collect rock samples and chart lunar maria and mountain ranges, but to live and work on the moon.

The Italian Luigi Gonfalonieri suggests a possible itinerary for the first lunar expedition. According to his plan, the rocket with the first astronauts will land in Sinus Iridium ("Bay of Rainbows") in the north-western part of Mare Imbrium ("Sea of Showers"). Mare Imbrium is one of the biggest and flattest of the moon's plains and offers the best surface for landing. Gonfalonieri thinks that one day it will become the main "astroport" for travel between the earth and moon and to other planets.

Sinus Iridium is located some 1,000 kilometres from the moon's North Pole. The first moon journey will be carried out in heavy-duty atom-powered cross-country vehicles. Leaving Sinus Iridium in a westerly direction the expedition will have on its left a mountain range separating it from Mare Frigoris ("Cold Sea") and in the distance the Alps, which they will cross through the Alpine Valley, a great gash 10 kilometres wide and 150 kilometres long cutting through the mountain range. This remarkable straight feature was probably ploughed through by a glancing meteorite. To reach the valley the expedition must cross the whole northern part of Mare Imbrium. After travelling 400 kilometres (250 miles) the travellers will see a sharp peak in the distance. This is Pico, a precipitous peak towering 2,000 metres (6,500 feet) high some 100 kilometres (65 miles) from the spurs of

the Alps. Several hours after passing Pico, the expedition will reach the Alps, a mountain range stretching out for 200 kilometres (125 miles). The Alpine Valley, which connects Mare Imbrium and Mare Frigoris, cuts the range precisely in half.

The expedition will pass through the valley and turn to the south, towards Mare Serenitatis ("Sea of Serenity"), which lies beyond the Caucasian Mountains. On the way it will pass the crater Eudoxus from the base of which a lowland extends for more than 1,600 kilometres (1,000 miles) to Mare Nectaris ("Sea of Nectar"). On the southern "shore" of Mare Nectaris there is a semicrater, somewhat resembling Sinus Iridium, in the wall of which there is a vast cavern which would be an excellent shelter for the moon explorers during the 15-day lunar night. From there the members of the expedition will probably have to continue on foot as the rugged surface in the direction of Tycho, the great ray crater on the suggested itinerary, will be too difficult for the vehicles to negotiate. With small rocket motors enabling them to make tremendous leaps over obstacles strapped to their backs the travellers would not find it very difficult to cover the 1,400 kilometres (870 miles) across the Altai Mountains and other features.

Tycho makes its presence apparent a long way away. Ray craters like Tycho sparkle in the sun as if they were covered with ice. The rays are probably made of a glass-like material deposited by the explosions in which the craters were formed. The first men on the moon will collect samples of lunar rock and dust, which may be

found to consist of known minerals and to contain some known types of organic molecules.

Whether the first expedition to the moon will be anything like the one outlined above or not, we may be quite sure that the first men on the moon will bring back to earth plenty of rock samples. Some will be delivered in hermetically sealed boxes for scientists to investigate them for traces of any living organism which, for all we know, may exist on the moon.

Another important task for the first lunar expedition will be to install automatic instruments for collecting and transmitting data long after the expedition departs. These installations will be powered by solar and nuclear batteries and their antennae will be permanently trained on the earth.

After one or more expeditions the time will come for the establishment of a permanent base on the moon. Already today moon architects are busy designing housing, storage depots and power, water producing and waste removal systems. One of the early tasks of moon expeditions will be to choose sites suitable for permanent stations. They should be flat, accessible and not too rocky or hard. The stations will have to be airtight, possibly in the shape of plastic domes. The astronauts will have to learn how to work in lunar conditions, how to dig pits and fill trenches, build bridges across crevices, sink wells, extract minerals, lift and transport loads, cut and weld metals, dig tunnels, and manipulate robots and other automatic hardware in lunar conditions. One of the important problems will be the generation of power for heating, lighting and

operating machinery. Possibly nuclear power plants will prove most suitable as they can ensure a continuous supply with minimum expenditure. They will be supplemented by solar batteries and heat chambers.

The absence of an atmosphere may pose many unusual problems, some of which will be hard to predict. It is known, for example, that in a high vacuum the coefficient of friction of two like surfaces is greater than in air. On the moon it may be sufficient to rub two surfaces together for them to stick firmly as if welded. On the other hand, this may make it hard to separate building materials stacked together without the necessary precautions or, for instance, to remove a nut from a spanner. Bearings and other mechanical systems will have to be devised so as to run without friction in lunar conditions. Conventional lubricants will evaporate there, and water, which on earth frequently acts as a lubricant, will be totally unsuitable. The small gravity on the moon may make winches and pulleys rather difficult to handle.

Another important problem is the storage of fuel for rockets commuting between the earth and the moon. This will prove to be a difficult task owing to the great temperature extremes between night and day. It will be necessary to build storage depots in places where the extremes are not so great and the sun's rays strike the surface at a small angle. The polar regions could be suitable, but owing to the small inclination of the moon's equator to the ecliptic the area around the poles with a fairly constant temperature (around -50°C) is very small. Fa-

avourable temperature conditions exist at the terminator (the boundary between day and night), but it moves along the surface as the moon turns on its axis with a speed ranging from zero at the poles to 15.4 km/hr (9.6 mph) at the equator. It would therefore appear that the poles are the most suitable places for establishing rocket landing and launching pads and propellant storage depots. If the storage tanks are dug into the ground the effects of temperature changes can be eliminated. The thermal conductivity of the outer layer of the moon is not great and as little as three feet from the surface the temperature of the soil may well be fairly constant.

People on the moon will probably find most, if not all, the chemical elements which man uses for power production on earth. One can expect, therefore, that in time moon expeditions will be able to produce energy on their own, thus making good much of the expenditure incurred in the first flights. The inconvenience of airlessness may be turned to good purpose if methods of storing energy in inertial flywheels are developed. Adequate power supply will solve the problem of providing the conditions needed for living and working there. Water extracted from minerals will meet the demands of people and machines, and electrolysis of water will provide oxygen for breathing and hydrogen for rocket fuels.

It seems evident that, at least in the initial stages of its evolution, the moon possessed many of the metals and nonmetals we know on earth. The first explorers will study their present distribution in the lunar crust. Insofar as this may be like the earth's in many respects (not taking

into account the different mechanical and chemical erosion factors) mineral prospecting and extraction methods will probably not differ considerably from the methods employed on earth.

We know very little of the chemistry of planets and their satellites. Chemists will therefore have plenty to do on the moon. They may find some new substances which, in the opinion of Professor V. K. Nikiforov, will provide important clues and experience for the investigation of celestial bodies of unknown chemical structure.

The moon is of interest to scientists working in many different fields. Astronomers will be able to carry on their observations day and night, as the stars shine continuously in the sky. They will not be plagued by interference due to atmospheric disturbances, to say nothing of clouds. Physicists will be able to study undistorted light and radio waves from other sources, as well as electromagnetic radiation and primary cosmic rays. This will enable them to penetrate deeper into the mysteries of the structure of matter and to solve, among other things, the problem of controlled thermonuclear reactions. To physicists the moon will present a vast laboratory with an almost ideal vacuum. Engineers may even devise a way of building huge electron tubes right on the surface. The moon may one day become a radio station for communication with the universe.

Science and technology are now advancing at such a rate that even the boldest flights of fancy often cannot keep up with reality.

When will the first manned flight to the moon take place? Not so long ago this would have appeared to be a premature question indeed. So much

has to be done before this can be accomplished. Nowadays it is on the order of the day. To be sure, we still cannot name precise the date or even month. Many engineering problems have yet to be solved. But the landing of Luna 9 on the moon is testimony to the fact that manned flight to the earth's eternal attendant is not far off. It is always the first step that is the most difficult in science, and it is from the first step that people can judge of the magnitude of the scientists' exploit.

A Soviet pennant has been lying on the surface of the moon since 1959. In the course of 1965, Luna 5, Luna 7 and Luna 8 also reached the moon. Their flights were important in developing the soft landing systems without which man cannot hope to visit other celestial bodies.

Only five years before people were wondering what the first flight of man in space would be like and how he would get back to earth. Yuri Gagarin's was a great exploit, but today such flights have become practically routine.

The Soviet programme of space research is drawn up according to a well-thought-out sequence of tasks. Each new experiment is a step forward from the previous achievement and, at the same time, a point of departure for the pursuance of further investigations.

In the order of this sequence, on 3 February 1966, at 21 hours 40 minutes 30 seconds Moscow time, Luna 9 landed safely on the moon in a preset area near the lunar equator in the Ocean of Storms (*Oceanus Procellarum*). On the landing site it was dawn, a time when lighting conditions are most favourable for observations.

Soon after the station's equipment was checked and the sun had risen over the horizon, on command from the earth the television camera was switched on. It began to scan the moonscape and transmit the view to earth.

The photographs taken during the four T. V. transmissions from Luna 9 were flashed around the earth. For the first time people could see the sight a cosmonaut disembarking from his spaceship will see. Scientists have obtained important data about the nature of the lunar surface and its microstructure. Now we know that the moon has no perceptible dust layer and that the surface is strong enough to support the weight of a space vehicle. Scientists are able to speak with greater confidence of the possibility of establishing research stations and observatories on the moon.

The first soft landing on the moon represents an outstanding achievement of Soviet science and technology and an important new step in the conquest of outer space. In the very near future it will be possible to carry out much more detailed explorations of the moon's surface with automatic instruments, thereby paving the way for future manned flight to our celestial neighbour. And who knows what new discoveries will have been made by the time this book falls into your hands, dear reader.



14. THE CALL OF THE COSMOS



The trail blazed into space by the first Soviet artificial earth satellite has become a wide road to the stars along which space rockets, automatic interplanetary stations and manned orbital spaceships have ascended to the heavens. But the beginning of the assault on the cosmos must be antedated not to October, 4, 1957, nor even to the first rockets launched by enthusiasts in the 1930s. Grateful mankind will forever remember October 1917, when the world's first socialist state was created. The world has seen with wonder and admiration how infinitely the boundaries of human achievement have been pushed back where Peace, Labour, Freedom, Equality and Brotherhood have become the basic rules of life.

On October 4, 1957, mankind scored its first victory over terrestrial gravitation. Only eight years have passed since that day, yet so much has been achieved. The triumphant signals of the first herald in outer space had hardly fallen silent when the first cosmic traveller, the dog Laika, was carried aloft in Sputnik 2. These were followed by other Soviet and American artificial satellites. Then in 1959 mankind marked another triumph over the eternal shackles of terrestrial gravitation. The first three Soviet moon probes exceeded the escape velocity and left the earth forever, one of them becoming a man-made planet of the solar system.

The transition from satellites to space rockets represented a new stage in the exploration of the universe. It signalled the possibility of solving many new scientific and technological problems, the development of powerful multi-stage rockets and flight control systems and complex scientific, measuring, radio telemetering and other systems for transmitting back to earth new information from outer space.

The year 1960 marks the beginning of purposeful preparation for manned space flight. Three heavy Soviet orbital spaceships invaded the neighbourhood of the earth. Together with launchings in the beginning of 1961, they enabled Soviet scientists and engineers to solve the problem of manned space flight. Their work was crowned with success on April 12, 1961, when Yuri Gagarin became the first human being to travel in space. Four months after him Gherman Titov repeated his exploit and stayed up for more than 24 hours. Other Soviet cosmonauts have

travelled millions of kilometres in outer space in journeys lasting several days.

Space conquest is steadily gaining impetus. Manned spaceships have travelled two at a time, the first woman, Valentina Tereshkova, has joined the ranks of cosmonauts, vehicles for crews of two and three astronauts have been built, a Soviet crew made up of an astronaut, engineer and doctor has flown in space. Several automatic laboratories have reached the neighbourhood of Venus and Mars and sent back important information. In the Soviet Union manoeuvrable space vehicles of the Polyot series have been developed, many rockets have been used to launch several satellites at a time and television and radio communication satellites have been orbited. Spaceships have been controlled at distances of millions of kilometres, and the Soviet Mars 1 automatic interplanetary station maintained communication with the earth up to a distance of 106 million kilometres. These are some of the results of the first eight years. And what next? We shall undoubtedly soon be witnessing more and more outstanding achievements and breakthroughs. Soviet people have opened the doors into outer space and they will continue to lead in its exploration. We are at the threshold of new cosmic missions. The Soviet Union has become a shore on the great ocean of the universe and many ships are destined to set off on new exploratory missions. The moon will doubtless be the first cosmic body on which earthmen set foot. It is hard to say when this will happen, but the time is not far off. This will be a great new achievement of mankind, a triumph of progress, reason.

TO THE READER

*Peace Publishers would be glad to have
your opinion on the translation and the de-
sign of this book.*

*Please send all suggestions to:
2, Pervy Rizhsky Pereulok,
Moscow, U.S.S.R.*

Printed in the Union of the Soviet Socialist Republics

OTHER PEACE PUBLISHERS' POPULAR SCIENCE BOOKS:

Anfilov, G. PHYSICS AND MUSIC. 220 pp.

The key-note of the book is man's desire to penetrate the world of the beautiful with exact sciences—physics, mathematics, and electronics—so as to place it within the reach of the man in the street.

Asratyan, E., Simonov, P. RELIABILITY OF THE BRAIN. 140 pp.

Acute problems of contemporary neurophysiology related to the problem of the elimination of functional disorders of the central nervous system.

Emme, A. THE CLOCK OF LIVING NATURE. 180 pp.

The book treats on the very interesting problem of biological rhythms. The reader makes a fascinating journey into the world of living nature. It is shown that all living creatures are capable of measuring time.

Malakhov, A. THE MYSTERY OF THE EARTH'S MANTLE. 200 pp.

The book tells how modern science is prying into the secrets of the Earth's depths. The latest discoveries and hypotheses are expounded.

Rusin, N., Fliit, L. MAN VERSUS CLIMATE. 150 pp.

An entertaining story of purposeful changes of the climate and weather. Artificial rain and microclimate, the prospects of the utilization of electric and atomic energy, as well as solar energy for the purpose of changing the natural conditions.

Shvarts, A. THE CODE OF LIFE. 200 pp.

The book is devoted to the mystery of heredity.

Steingauz, A. THE NINE COLOURS OF THE RAINBOW. 300 pp.

ABOUT THE BOOK

The day is not far off when a spaceship will land on one of the moon's vast plains and the first earthmen will step out onto lunar soil. Scientists and engineers are hard at work preparing for that great day. Automatic probes have reconnoitred the path to the moon, photographed its unseen side, taken close-up pictures of the visible side and answered questions the gravitational and magnetic fields and radiation belts in outer space. Several rockets have hit the moon. The next step is a manned trip to the earth's natural satellite.

How men are preparing for a trip to the moon, what dangers astronauts may face there, and how astronautics may be expected to develop in future the subjects are some of the subjects discussed in this book.

MIR PUBLISHERS MOSCOW